US009111778B2

(12) United States Patent
Emerson et al.

(10) Patent No.: US 9,111,778 B2
(45) Date of Patent: Aug. 18, 2015

(54) LIGHT EMITTING DIODE (LED) DEVICES, SYSTEMS, AND METHODS

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 304 days.

(21) Appl. No.: **13/011,609**

(22) Filed: **Jan. 21, 2011**

(65) **Prior Publication Data**

US 2012/0153317 A1 Jun. 21, 2012

Related U.S. Application Data

(63) Continuation-in-part of application No. 12/969,267, filed on Dec. 15, 2010, now Pat. No. 8,686,445.

(51) **Int. Cl.**

H01L 33/08 (2010.01)
H01L 25/075 (2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H01L 25/0753*** (2013.01); ***G02F 1/133603*** (2013.01); *G02F 1/133608* (2013.01); *H01L 24/48* (2013.01); *H01L 33/486* (2013.01); *H01L 33/60* (2013.01); *H01L 33/62* (2013.01); *H01L 33/642* (2013.01); *H01L 2224/2929* (2013.01); *H01L 2224/29144* (2013.01); *H01L 2224/29399* (2013.01); *H01L 2224/48091* (2013.01); *H01L 2224/48247* (2013.01); *H01L 2224/83192* (2013.01); *H01L 2224/92247* (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC H01L 2224/48091; H01L 2924/01322; H01L 33/60; H01L 33/486; H01L 2224/29111; H01L 33/642; H01L 33/405; H01L 33/52; H01L 2924/14

USPC 257/88, 89, 98, E23.055; 438/28

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,946,547	A	8/1990	Palmour
5,200,022	A	4/1993	Kong

(Continued)

FOREIGN PATENT DOCUMENTS

CN	101142692	A	3/2008
CN	201054361		4/2008

(Continued)

OTHER PUBLICATIONS

Non-Final Office Action for Korean Application Serial No. KR 30-2010-0047048 dated Dec. 15, 2011.

(Continued)

Primary Examiner — Roy Potter

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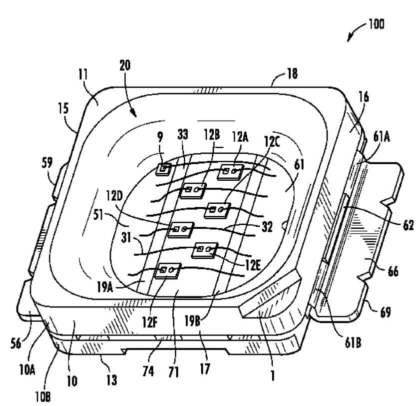
(57) **ABSTRACT**

Light emitting diode (LED) devices, systems, and methods are disclosed. In one aspect, an illumination panel can be configured to provide backlighting for a liquid crystal display (LCD) panel. The illumination panel can include one or more LEDs arranged in an array. The one or more LEDs can be attached using metal-to-metal die attach methods over an illumination panel, or attached within packages disposed over the illumination panel. In one aspect, the one or more LEDs can be attached using robust metal-to-metal die attach techniques and/or materials disclosed herein.

126 Claims, 15 Drawing Sheets



(51) **Int. Cl.**

G02F 1/1335	(2006.01)
H01L 23/00	(2006.01)
H01L 33/48	(2010.01)
H01L 33/60	(2010.01)
H01L 33/62	(2010.01)
H01L 33/64	(2010.01)

(52) **U.S. Cl.**

CPC *H01L2924/00014* (2013.01); *H01L 2924/01019* (2013.01); *H01L 2924/01079* (2013.01); *H01L 2924/01322* (2013.01); *H01L 2924/10157* (2013.01); *H01L 2924/10158* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,210,051	A	5/1993	Carter, Jr.
RE34,861	E	2/1995	Davis et al.
5,393,993	A	2/1995	Edmond
5,506,446	A	4/1996	Hoffman et al.
5,523,589	A	6/1996	Edmond
6,274,924	B1	8/2001	Carey et al.
6,498,355	B1	12/2002	Harrah
6,806,583	B2	10/2004	Koay et al.
6,828,170	B2	12/2004	Roberts et al.
6,921,927	B2	7/2005	Ng et al.
6,936,855	B1	8/2005	Harrah
6,949,771	B2	9/2005	Yoganandan et al.
7,098,483	B2	8/2006	Mazzochette et al.
7,253,448	B2	8/2007	Roberts et al.
7,361,940	B2	4/2008	Kim et al.
7,566,159	B2	7/2009	Oon et al.
D597,968	S	8/2009	Kobayakawa et al.
7,592,638	B2	9/2009	Kim
7,659,551	B2	2/2010	Loh
7,692,206	B2	4/2010	Loh
D622,680	S	8/2010	Lin et al.
7,791,061	B2	9/2010	Edmond et al.
D626,095	S	10/2010	Hsieh
D627,310	S	11/2010	Lin et al.
D628,541	S	12/2010	Lin
7,852,015	B1	12/2010	Yen et al.
7,858,993	B2	12/2010	Kong et al.
D632,267	S	2/2011	Chen et al.
D632,659	S	2/2011	Hsieh
D634,284	S	3/2011	Ko et al.
D634,285	S	3/2011	Ko et al.
D634,286	S	3/2011	Ko et al.
D634,716	S	3/2011	Suzuki
D641,719	S	7/2011	Hussell et al.
D643,819	S	8/2011	Joo
D648,686	S	11/2011	Hussell et al.
D648,687	S	11/2011	Joo et al.
D658,599	S	5/2012	Takahashi et al.
D659,657	S	5/2012	Hussell et al.
D661,264	S	6/2012	Joo et al.
D667,801	S	9/2012	Joo et al.
8,269,244	B2	9/2012	Hussell
8,354,992	B2 *	1/2013	Rumreich et al. 345/102
D679,842	S	4/2013	Joo et al.
8,497,522	B2	7/2013	Hussell
8,598,602	B2	12/2013	Hussell
8,610,140	B2	12/2013	Joo
8,648,359	B2	2/2014	Hussell
8,686,445	B1	4/2014	Hussell et al.
D704,358	S	5/2014	Joo et al.
D708,156	S	7/2014	Joo et al.
2001/0045640	A1	11/2001	Oida et al.
2004/0075100	A1	4/2004	Bogner et al.
2004/0079957	A1	4/2004	Andrews et al.
2004/0087057	A1	5/2004	Wang et al.
2005/0269587	A1	12/2005	Loh et al.
2006/0043401	A1	3/2006	Lee et al.
2006/0118808	A1	6/2006	Sadamu et al.
2006/0157726	A1	7/2006	Loh et al.
2006/0186418	A1	8/2006	Edmond et al.
2007/0052074	A1	3/2007	Hasegawa
2007/0057364	A1	3/2007	Wang et al.
2007/0114514	A1	5/2007	Shin
2007/0262328	A1	11/2007	Bando
2008/0023722	A1	1/2008	Lee et al.
2008/0048201	A1	2/2008	Kim et al.
2008/0185605	A1	8/2008	Wada et al.
2008/0258130	A1	10/2008	Bergmann et al.
2008/0278941	A1	11/2008	Logan et al.
2008/0283849	A1	11/2008	Imai
2009/0008662	A1	1/2009	Ashdown et al.
2009/0101921	A1	4/2009	Lai
2009/0121249	A1	5/2009	Tseng et al.
2009/0122533	A1 *	5/2009	Brukilacchio 362/231
2009/0159905	A1	6/2009	Chen
2009/0267085	A1	10/2009	Lee et al.
2009/0321779	A1	12/2009	Chang et al.
2010/0059783	A1	3/2010	Chandra
2010/0102345	A1	4/2010	Sung et al.
2010/0155748	A1	6/2010	Chan et al.
2010/0163887	A1	7/2010	Kim et al.
2010/0181582	A1	7/2010	Li et al.
2010/0210048	A1	8/2010	Urano
2010/0237360	A1	9/2010	Kao et al.
2010/0270577	A1	10/2010	Rulkens et al.
2011/0006658	A1	1/2011	Chan
2011/0090711	A1	4/2011	Kim
2011/0180827	A1	7/2011	Hussell
2011/0186873	A1	8/2011	Emerson
2011/0316022	A1	12/2011	Hussell
2012/0069560	A1	3/2012	Miskin et al.
2012/0127720	A1	5/2012	Hussell et al.
2012/0307481	A1	12/2012	Joo et al.
2013/0003375	A1	1/2013	Hussell
2013/0011946	A1	1/2013	Hussell
2014/0027801	A1	1/2014	Hussell
2014/0159088	A1	6/2014	Hussell et al.
2014/0217434	A1	8/2014	Hussell et al.

FOREIGN PATENT DOCUMENTS

CN	101432896	5/2009
CN	101765627 A	6/2010
CN	200930286397.5	10/2010
CN	ZL 2011-30010728	1/2012
CN	ZL201130171313.0	4/2012
EP	1 756 879	1/2009
EP	001242234	1/2011
EP	2 438 631	4/2012
EP	2 603 930	6/2013
EP	2 628 196	8/2013
JP	D1102760	3/2001
JP	2009-016636	1/2002
JP	2002-280616	9/2002
JP	2005-179147	7/2005
JP	2005-209763	8/2005
JP	2006-093470 WO	4/2006
JP	2006-173561	6/2006
JP	2007-108547	4/2007
JP	2007-335762	12/2007
JP	2008-071954	3/2008
JP	2008-091792	4/2008
JP	2008-098218	4/2008
JP	2008-103480	5/2008
JP	2008-147611	6/2008
JP	2008-533716	8/2008
JP	2008-545269	12/2008
JP	D1346959	12/2008
JP	3154368	9/2009
JP	2010-034262	2/2010
JP	2010-205776	9/2010
JP	1416396	5/2011
JP	1431637	12/2011
JP	1433335	1/2012
JP	D1433030	1/2012
JP	1441805	4/2012
KR	10-0591687	6/2006

(56) **References Cited**

FOREIGN PATENT DOCUMENTS

KR	1020070000130	A	1/2007
KR	10-2007-0055361		5/2007
KR	10-0845856		7/2008
KR	1020090003378	A	1/2009
KR	10-0967451		7/2010
KR	30-0681227		2/2013
KR	30-0697636		6/2013
TW	200711166		3/2007
TW	200928203		7/2009
TW	M376909		3/2010
TW	201013969		4/2010
TW	M383822		7/2010
TW	100305347		3/2012
TW	D146222		4/2012
TW	D148144		7/2012
WO	WO 2006/059828		6/2006
WO	WO 2006/095949		9/2006
WO	WO 2007/126720		11/2007
WO	WO 2008/002088		1/2008
WO	WO 2008/021268		2/2008
WO	WO 2008/069204		6/2008
WO	WO-2010/141215		3/2011
WO	WO 2012/005984		1/2012
WO	WO 2012/021238		2/2012
WO	WO 2012/050994		4/2012
WO	WO 2012/100060		7/2012
WO	WO 2012/106312		8/2012
WO	WO 2012/109225		8/2012
WO	WO 2012/151270		11/2012

OTHER PUBLICATIONS

Non-Final Office Action for Korean Application Serial No. KR 30-2010-0047049 dated Dec. 15, 2011.
Notification of Grant for Chinese Application Serial CN 2011/30210595.0 dated Jan. 17, 2012.
Notification of Grant for Chinese Application Serial No. CN 2010-305787293.2 dated Jan. 19, 2012.
Notice of Allowance for U.S. Appl. No. 29/401,692 dated Jan. 20, 2012.
Notice of Allowance for U.S. Appl. No. 29/403,433 dated Feb. 2, 2012.
International Search Report for Application Serial No. TW 100305347 dated Mar. 5, 2012.
Japanese Notice of Allowance for Application Serial No. JP 2011-017747 dated Mar. 13, 2012.
Communication of European publication number and information on the application of Article 67(3) EPC dated Mar. 14, 2012.
Non-Final Office Action for U.S. Appl. No. 13/082,699 dated Apr. 13, 2012.
Notice of Allowance for U.S. Appl. No. 29/397,017 dated May 17, 2012.
Notice of Allowance for U.S. Appl. No. 12/853,812 dated May 21, 2012.
International Search Report and Written Opinion for Application Serial No. PCT/US2011/054560 dated May 22, 2012.
Supplemental Notice of Allowance for U.S. Appl. No. 29/397,017 dated Jul. 23, 2012.
Hyun-Ho Kim et al., Thermal Transient Characteristics of Die Attach in High Power LED PKG, Microelectronics Reliability, vol. 48, Issue 3, Mar. 2008, pp. 445-454.
Notice of Allowance from U.S. Appl. No. 29/330,657 dated Sep. 25, 2009.
Taiwanese Notice of Allowance for Application No. 100305347 dated Mar. 23, 2012.
Certificate of Design Patent for Chinese Application Serial No. CN ZL 201130171313 dated May 7, 2012.
Certificate of Design Patent for Application Serial No. CN ZL 201130210595 dated Jun. 11, 2012.
Certificate of Design Patent for Application Serial No. CN ZL 201030577293 dated May 23, 2012.
International Search Report for Application Serial No. PCT/US2012/023285 dated Jun. 27, 2012.
Korean Office Action for Application Serial No. KR 30-2011-27243 dated Jul. 5, 2012.
Korean Office Action for Application Serial No. KR 30-2011-27244 dated Jul. 5, 2012.
Korean Office Action for Application Serial No. KR 30-2011-27245 dated Jul. 5, 2012.
International Search Report and Written Opinion for Application Serial No. PCT/US2012/024122 dated Jul. 11, 2012.
Restriction Requirement for U.S. Appl. No. 29/382,394 dated Jul. 17, 2012.
Notification Concerning Availability of The Publication Serial No. PCT/US2012/023285 dated Aug. 9, 2012.
Notification Concerning Availability of The Publication Serial No. PCT/US2012/024122 dated Aug. 16, 2012.
Korean Office Action for Application Serial No. KR 30-2010-0047049 dated Sep. 12, 2012.
International Search Report and Written Opinion for Application Serial No. PCT/US2012/021879 dated Sep. 21, 2012.
International Search Report and Written Opinion for Application Serial No. PCT/US2012/036110 dated Oct. 4, 2012.
Notice of Allowance for U.S. Appl. No. 13/082,699 dated Oct. 23, 2012.
Korean Decision to Grant for Application No. KR 30-2011-0027245 dated Nov. 19, 2012.
Korean Decision to Grant for Application No. KR 30-2011-0027244 dated Nov. 19, 2012.
Korean Decision to Grant for Application No. KR 30-2011-0027243 dated Nov. 26, 2012.
Korean Decision to Grant for Application No. KR 30-2010-0047048 dated Nov. 26, 2012.
Notice of Allowance for U.S. Appl. No. 29/382,394 dated Nov. 27, 2012.
Supplemental Notice of Allowance for U.S. Appl. No. 29/382,394 dated Jan. 14, 2013.
Non-Final Office Action for U.S. Appl. No. 13/462,450 dated Jan. 15, 2013.
Non-Final Office Action for U.S. Appl. No. 12/825,075 dated Feb. 1, 2013.
Non-Final Office Action for U.S. Appl. No. 13/227,961 dated Mar. 26, 2013.
Non-Final Office Action for U.S. Appl. No. 12/969,267 dated Mar. 29, 2013.
Notice of Allowance for U.S. Appl. No. 13/082,699 dated Apr. 3, 2013.
Korean Notice of Allowance for Application No. 30-2010-0047049 dated Apr. 4, 2013.
Non-Final Office Action for U.S. Appl. No. 13/362,683 dated Sep. 9, 2013.
Notice of Allowance for U.S. Appl. No. 29/432,988 dated Sep. 10, 2013.
Restriction Requirement for U.S. Appl. No. 29/451,761 dated Sep. 25, 2013.
Notice of Allowance for U.S. Appl. No. 13/227,961 dated Oct. 2, 2013.
Notice of Allowance for U.S. Appl. No. 12/969,267 dated Oct. 2, 2013.
Non-Final Office Action for U.S. Appl. No. 13/616,759 dated Oct. 10, 2013.
Non-Final Office Action for U.S. Appl. No. 13/616,759 dated Jul. 11, 2013.
Notice of Allowance for U.S. Appl. No. 12/825,075 dated Jul. 31, 2013.
Notice of Allowance for U.S. Appl. No. 13/462,450 dated Aug. 1, 2013.
Extended European Search Report for Application No. EP 10 78 3782 dated Nov. 22, 2013.
Restriction Requirement for U.S. Appl. No. 13/953,438 dated Dec. 5, 2013.
Japanese Office Action for Application No. 2012-513966 dated Dec. 9, 2013.

(56) **References Cited**

OTHER PUBLICATIONS

Notice of Allowance for U.S. Appl. No. 29/451,761 dated Dec. 11, 2013.
Description Model No. NS6x083x issued by Nichia Corporation—at least as early as Feb. 17, 2007.
Description Model No. NS6G083 issued by Nichia Corporation—at least as early as Aug. 31, 2007.
Notice of Allowance dated Apr. 16, 2010 from U.S. Appl. No. 29/338,186.
Design U.S. Appl. No. 29/360,791, filed Apr. 30, 2010.
Non-Final Office Action for U.S. Appl. No. 12/479,318 dated Jun. 2, 2010.
Related Design U.S. Appl. No. 29/365,939, filed Jul. 16, 2010.
U.S. Appl. No. 12/853,812 filed Aug. 10, 2010.
Notice of Allowance for U.S. Appl. No. 29/353,652 dated Aug. 24, 2010.
U.S. Appl. No. 61/404,985, filed Oct. 13, 2010.
Non-final Office Action for U.S. Appl. No. 12/479,318 dated Nov. 10, 2010.
Notice of Allowance for U.S. Appl. No. 29/353,652 dated Nov. 26, 2010.
Supplemental Notice of Allowance for U.S. Appl. No. 29/353,652 dated Dec. 8, 2010.
U.S. Appl. No. 12/969,267, filed Dec. 15, 2010.
Notice of Allowance for U.S. Appl. No. 29/360,791 dated Dec. 22, 2010.
Notice of Allowance for U.S. Appl. No. 29/365,939 dated Dec. 27, 2010.
Related Design U.S. Appl. No. 29/382,394, filed Jan. 3, 2011.
International Search Report/Written Opinion dated Jan. 5, 2011 for PCT/US2010/035379.
Certificate of Registration for Community Design Application Serial No. 001283600-0001-0003 dated Jan. 7, 2011.
U.S. Appl. No. 13/011,609, filed Jan. 21, 2011.
Supplemental Notice of Allowance for U.S. Appl. No. 29/360,791 dated Jan. 24, 2011.
Notice of Allowance for U.S. Appl. No. 12/479,318 dated Feb. 17, 2011.
Notice of Allowance for U.S. Appl. No. 29/338,186 dated Mar. 10, 2011.
Notice of Allowance for Japanese Design Appl. No. 2010-026186 dated Mar. 29, 2011.
Supplemental Notice of Allowability for U.S. Appl. No. 12/479,318 dated Apr. 5, 2011.
Japanese Office Action for JP2010-026185 dated Apr. 5, 2011.
Notice of Allowance for Design U.S. Appl. No. 29/360,791 dated Apr. 12, 2011.
Notice of Allowance for Design U.S. Appl. No. 29/365,939 dated Apr. 12, 2011.
Supplemental Notice of Allowance for Design U.S. Appl. No. 29/338,186 dated May 20, 2011.
Taiwanese Office Action for Appl. No. 099305566 dated Jul. 12, 2011.
Notice of Allowance for Design U.S. Appl. No. 29/360,791 dated Jul. 21, 2011.
Notice of Allowance for Design U.S. Appl. No. 29/380,549 dated Jul. 28, 2011.
Office Action with Restriction/Election Requirement for U.S. Appl. No. 12/853,812 dated Sep. 22, 2011.
International Search Report and Written Opinion for PCT Application Serial No. PCT/US2011/41833 dated Oct. 24, 2011.
International Search Report and Written Opinion for PCT Application Serial No. PCT/US2011/043539 dated. Oct. 28, 2011.
Notice of Allowance for Japanese Application Serial No. JP-DES 2011/015199 dated Nov. 10, 2011.
Notice of Allowance for Japanese Application Serial No. JP-DES 2011/015200 dated Nov. 30, 2011.
Notice of Allowance for Japanese Application Serial No. JP-DES 2011/015201 dated Nov. 30, 2011.
Notice of Allowance for Taiwanese Application Serial No. TW 099305566 dated Dec. 5, 2011.
Notice of Allowance for Chinese Application Serial No. CN 2011/30171313.0 dated Dec. 6, 2011.
Non-Final Office Action for U.S. Appl. No. 12/853,812 dated Dec. 7, 2011.
International Preliminary Report on Patentability for PCT Application Serial No. PCT/US2010/035379 dated Dec. 8, 2011.
Notice of Allowance for U.S. Appl. No. 29/397,017 dated Dec. 9, 2011.
Taiwanese Office Action for Application No. 100137044 dated Jul. 16, 2014.
Chinese Office Action for Application No. 201180041213.3 dated Aug. 4, 2014.
Chinese Office Action for Application No. 201080030486.3 dated Sep. 3, 2014.
Korean Office Action for Application No. 10-2013-7022968 dated Sep. 19, 2014.
Notice of Allowance for U.S. Appl. No. 13/953,438 dated May 13, 2014.
Japanese Office Action for Application No. 2012-513966 dated May 16, 2014.
Final Office Action for U.S. Appl. No. 13/362,683 dated Jun. 5, 2014.
Notice of Allowance for U.S. Appl. No. 13/019,812 dated Jun. 12, 2014.
Taiwanese Office Action for Application No. 100126672 dated Jun. 18, 2014.
Notice of Allowance for U.S. Appl. No. 13/616,759 dated Jul. 2, 2014.
Taiwanese Office Action and Search Report for Application No. 100126672 dated Dec. 26, 2013.
Chinese Office Action for Application No. 2010800304863 dated January 27, 2014.
Taiwanese Office Action for Application No. 101102722 dated Jan. 28, 2014.
Corrected Notice of Allowance for U.S. Appl. No. 12/969,267 dated Feb. 27, 2014.
Chinese Office Action for Application No. 201080030486.3 dated Mar. 11, 2014.
Japanese Office Action for Application No. 2013-533875 dated Mar. 11, 2014.
Korean Office Action for Application No. 10-2012-7031924 dated Mar. 17, 2014.
Final Office Action for U.S. Appl. No. 13/019,812 dated Mar. 27, 2014.
Taiwanese Office Action and Search Report for Application No. 101102722 dated Oct. 23, 2014.
Korean Office Action for Application No. 10 2013/7031905 dated Sep. 29, 2014.
Chinese Office Action for Application No. 2010/80030486.3 dated Dec. 17, 2014.
Chinese Decision to Grant for Application No. 201080030486.3 Dated Apr. 1, 2015.
Chinese Office Action for Application No. 201180043373.1 dated Mar. 2, 2015.
Chinese Office Action for Application No. 201180041213.3 dated Apr. 7, 2015.
Chinese Office Action for Application No. 201210068676.5 dated Feb. 15, 2015.
Chinese Office Action for Application No. 201280014461.3 dated Jan. 4, 2015.
Chinese Office Action for Application No. 201180029228.8 dated Jan. 12, 2015.
Taiwanese Office Action for Application No. 100137044 dated Feb. 24, 2015.

* cited by examiner

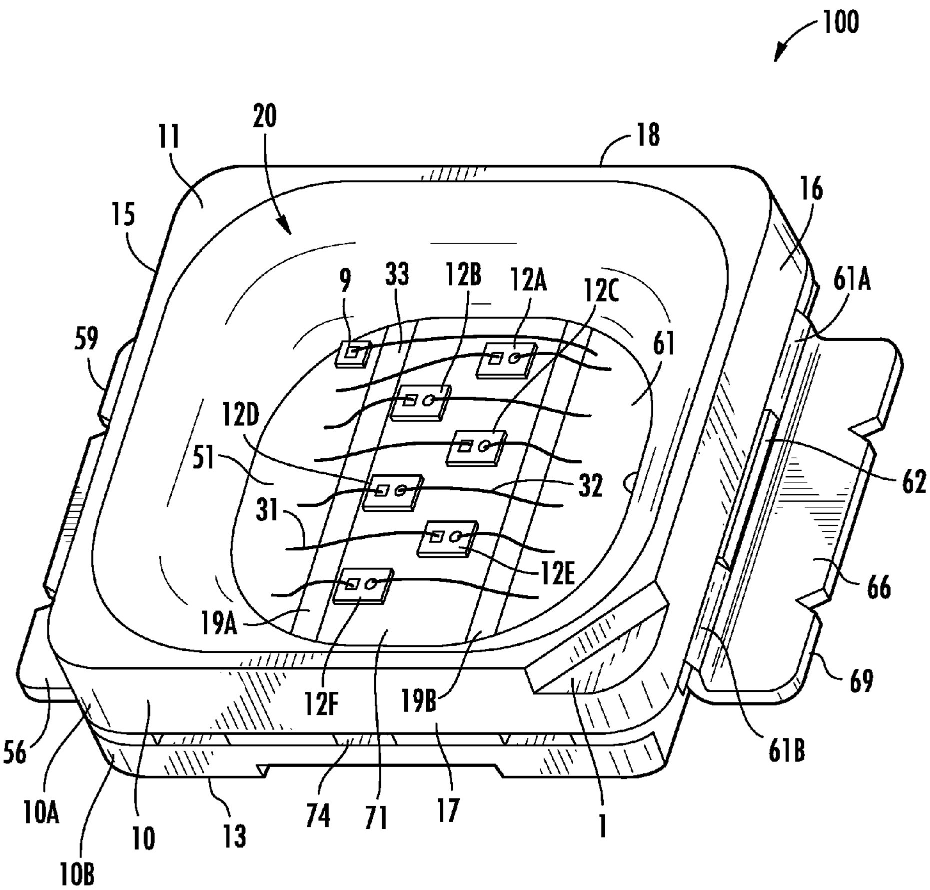


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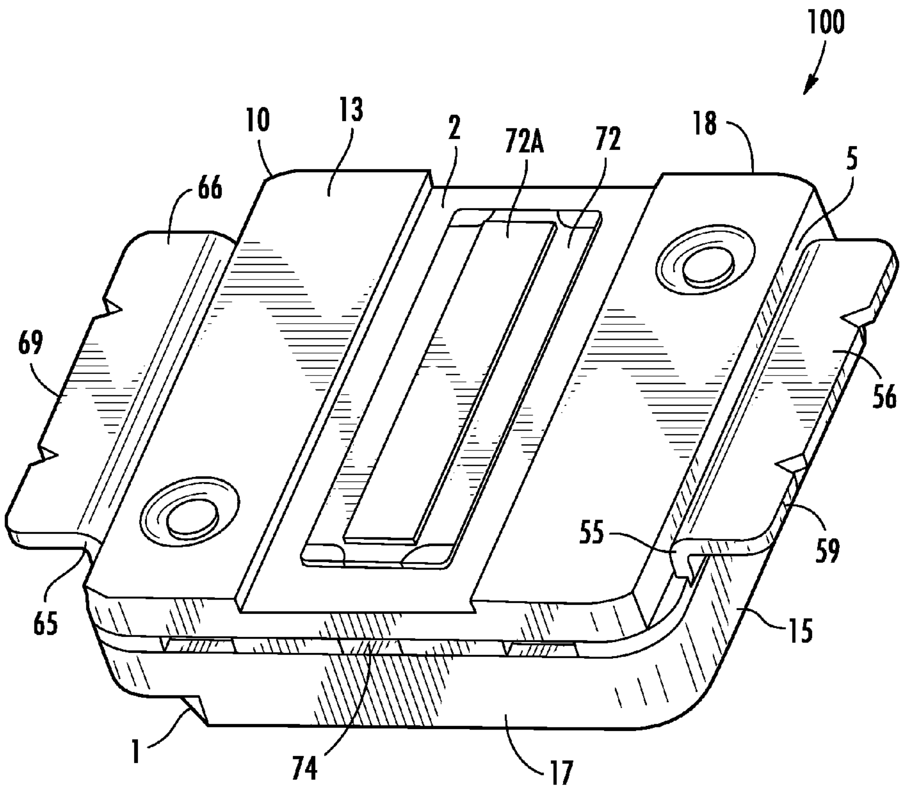
FIG. 1



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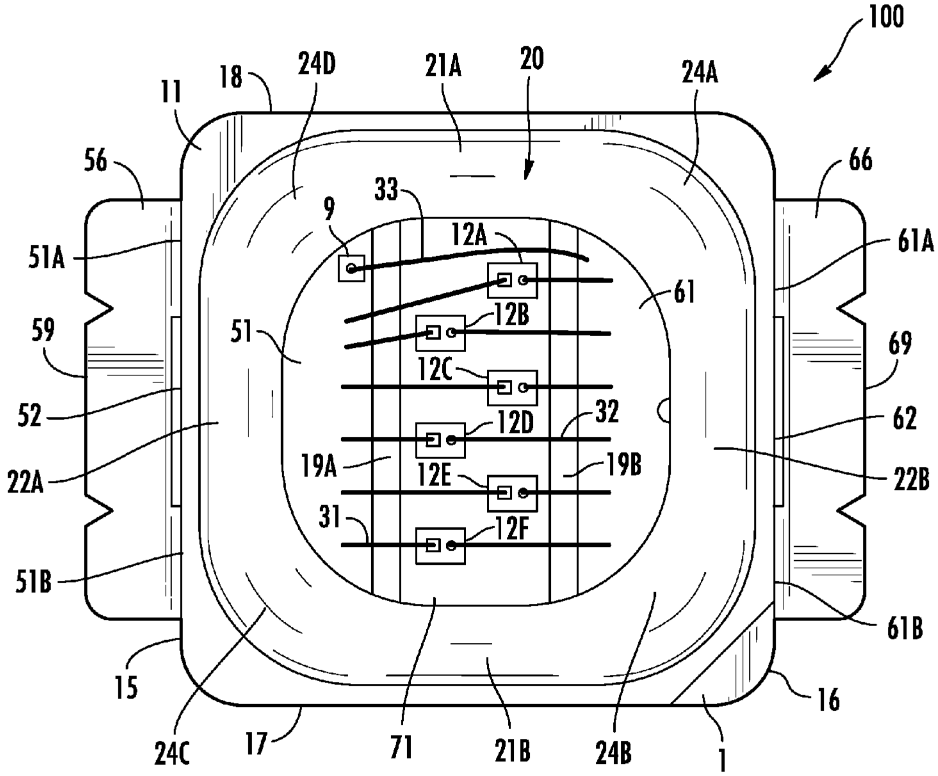
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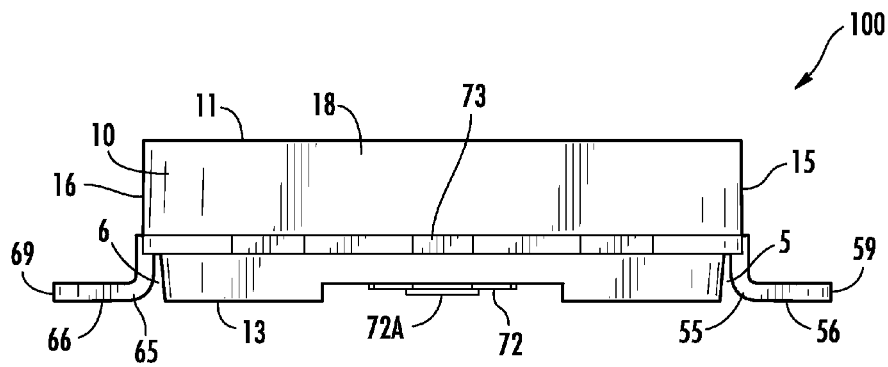
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56

FIG. 4

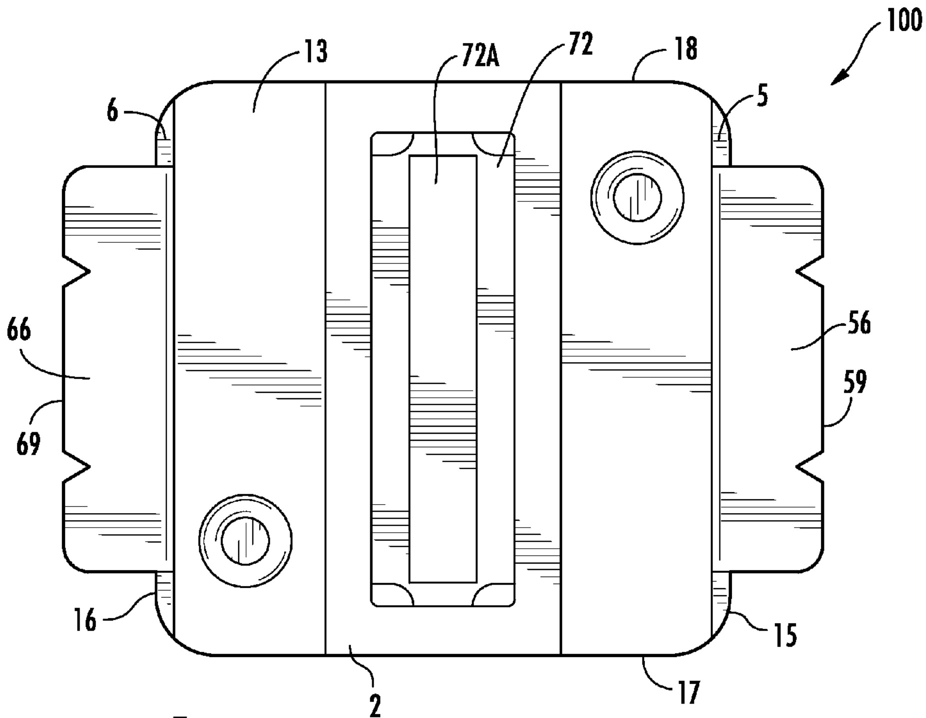
100
13
72A
72
18
6
5
66
69
56
59
16
15
2
17

FIG. 5

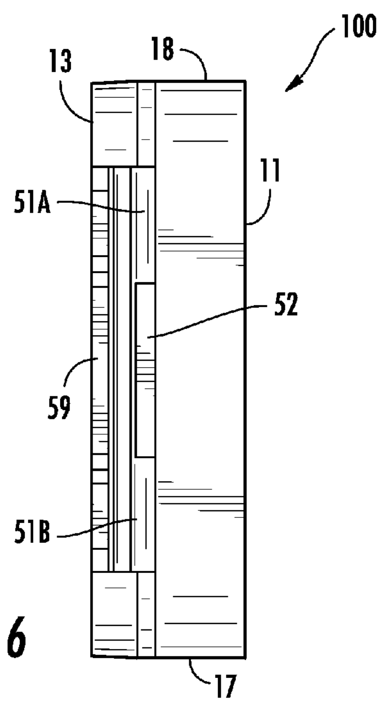
100
18
13
11
51A
52
59
51B
17

FIG. 6

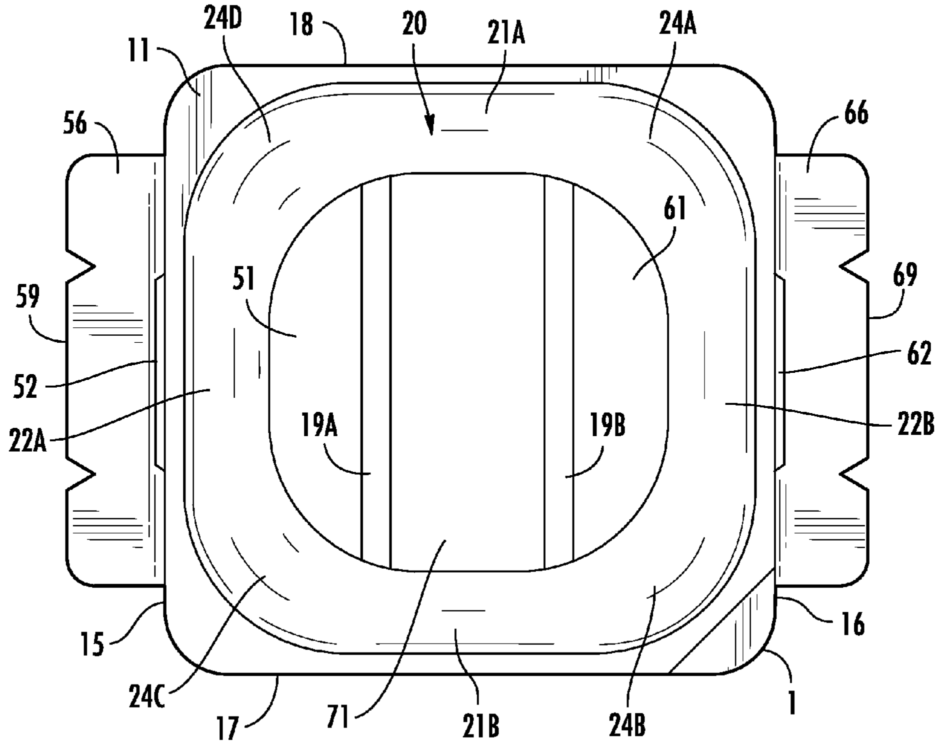
24D
18
20
21A
24A
11
56
66
61
51
69
59
52
62
22A
19A
19B
22B
15
16
24C
17
71
21B
24B
1

FIG. 7

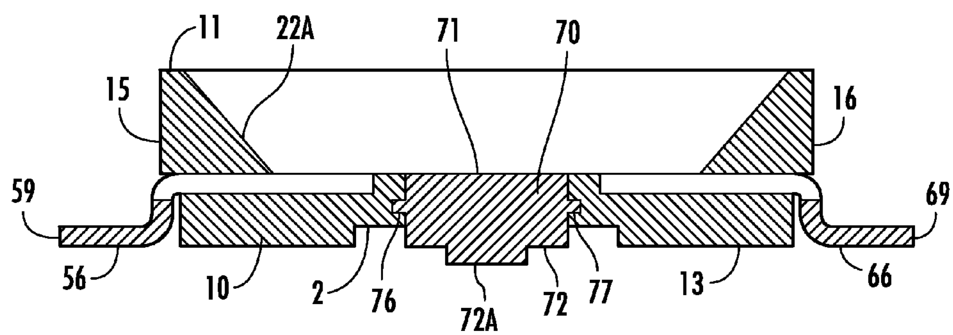
11
22A
71
70
15
16
59
69
56
10
2
76
72A
72
77
13
66

FIG. 9

FIG. 8A

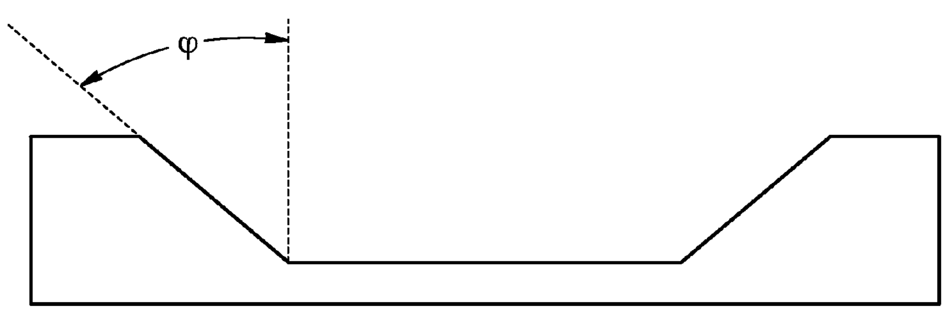

FIG. 8B

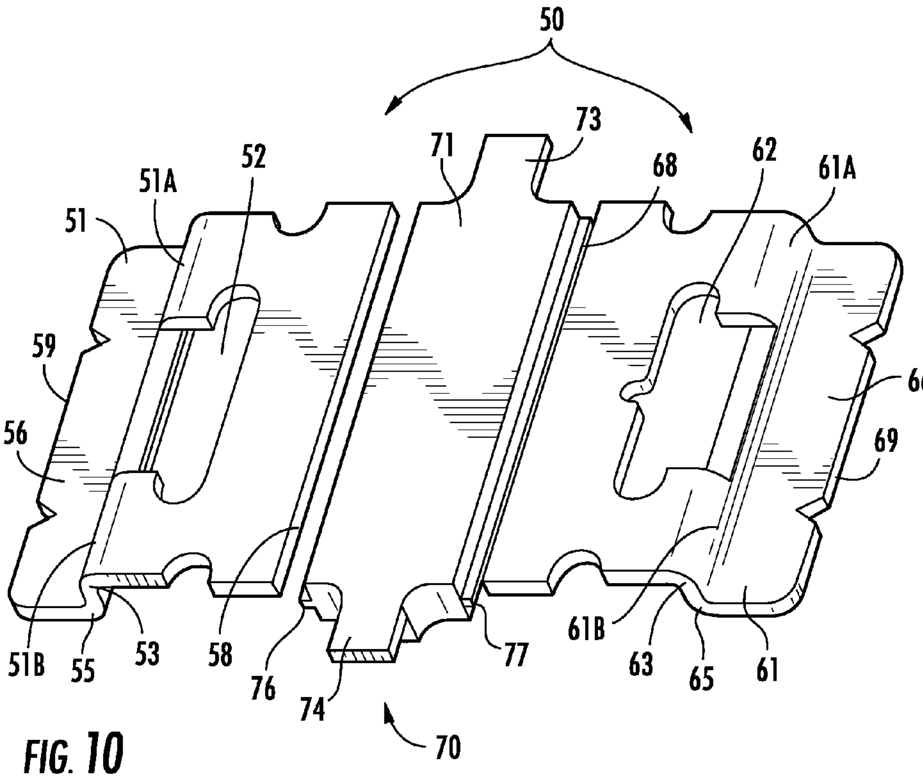
50
73
71
52
68
62
61A
51A
51
59
66
56
69
51B
55
53
58
76
74
77
61B
63
65
61
70

FIG. 10

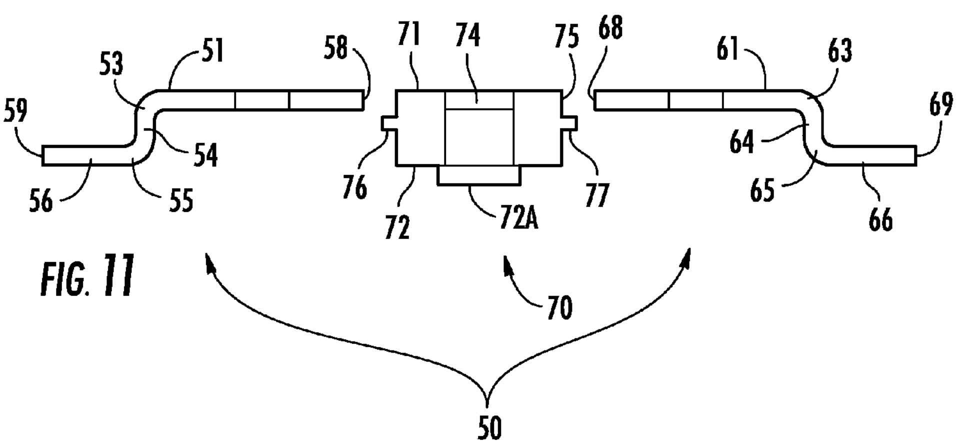
53
51
58
71
74
75
68
61
63
59
54
64
69
56
55
76
72
72A
77
65
66
70
50

FIG. 11

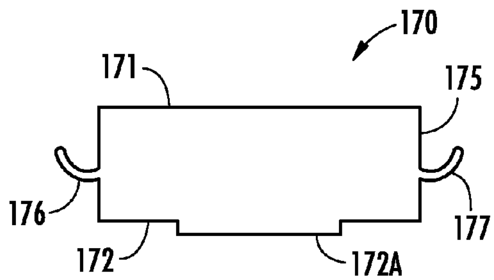

FIG. 12A

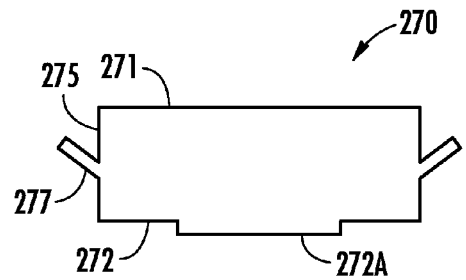

FIG. 12B

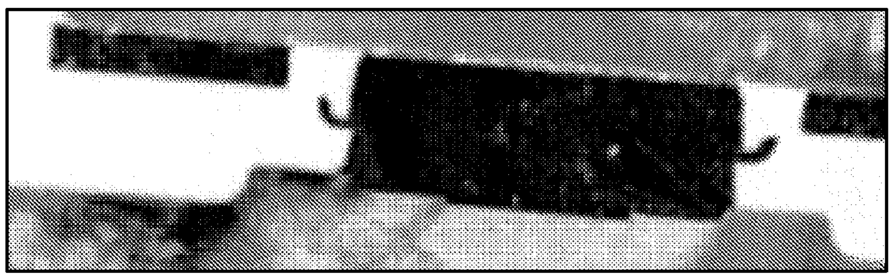

FIG. 12C

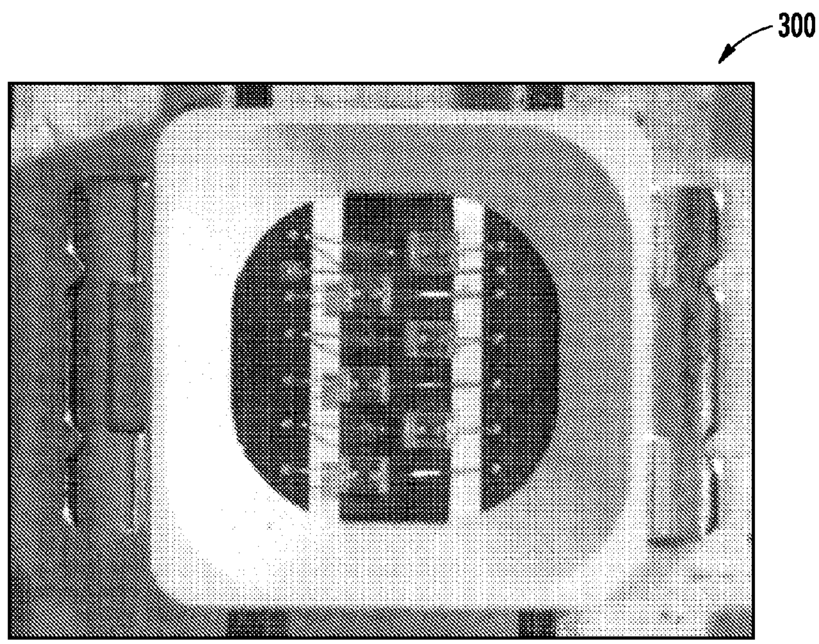

FIG. 13

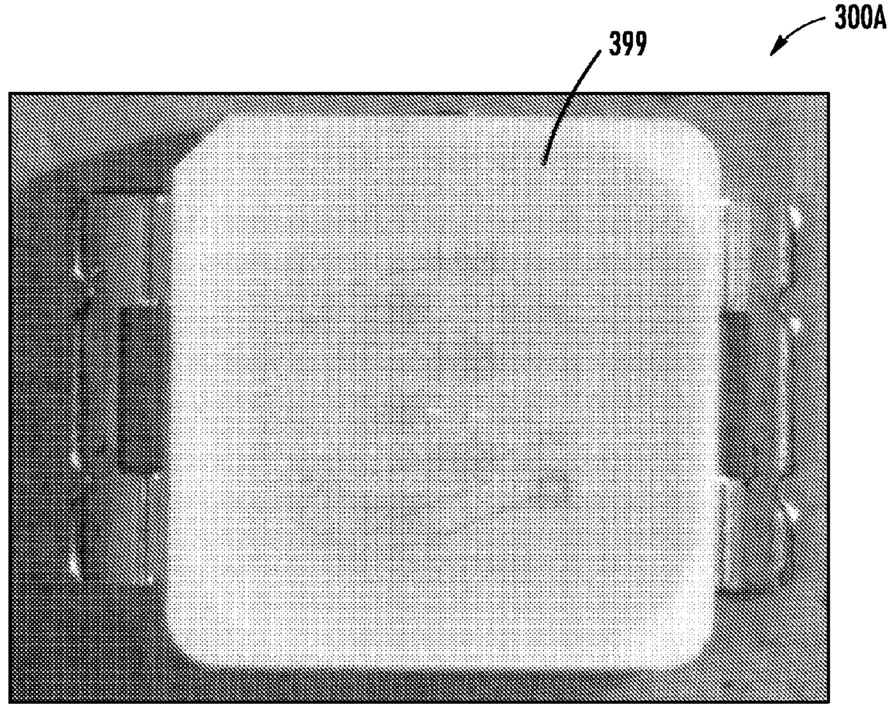

FIG. 14A

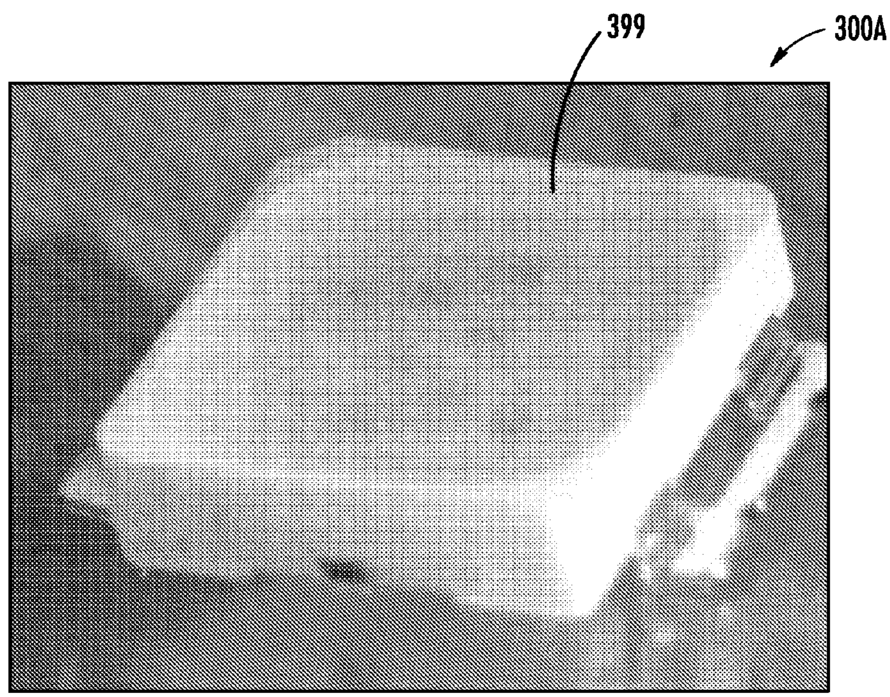

FIG. 14B

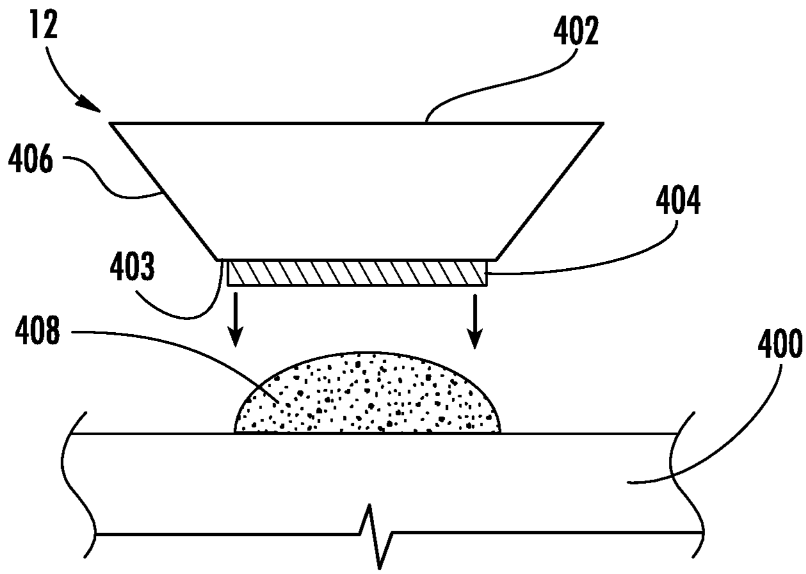

FIG. 15A

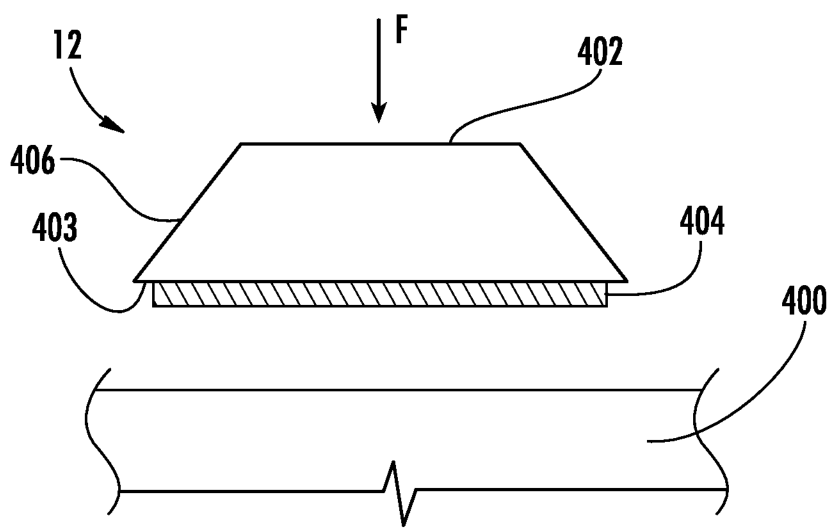

FIG. 15B

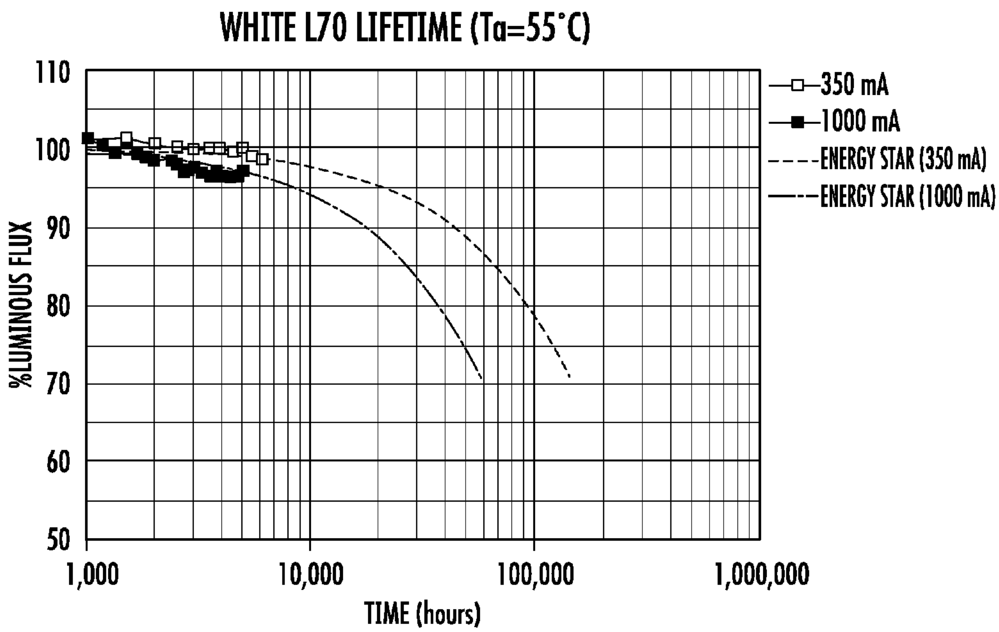

FIG. 16A

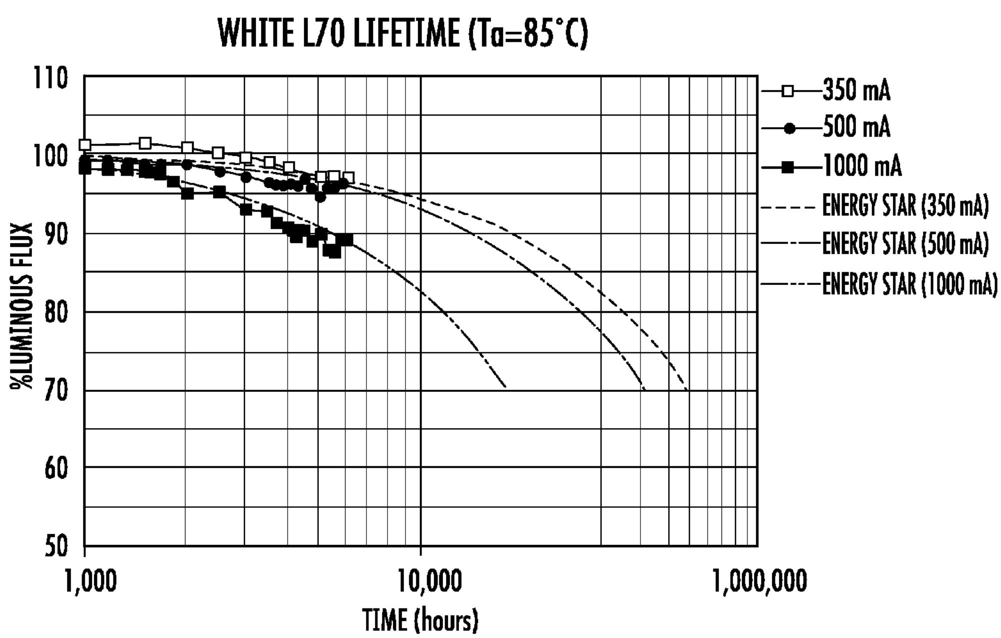

FIG. 16B

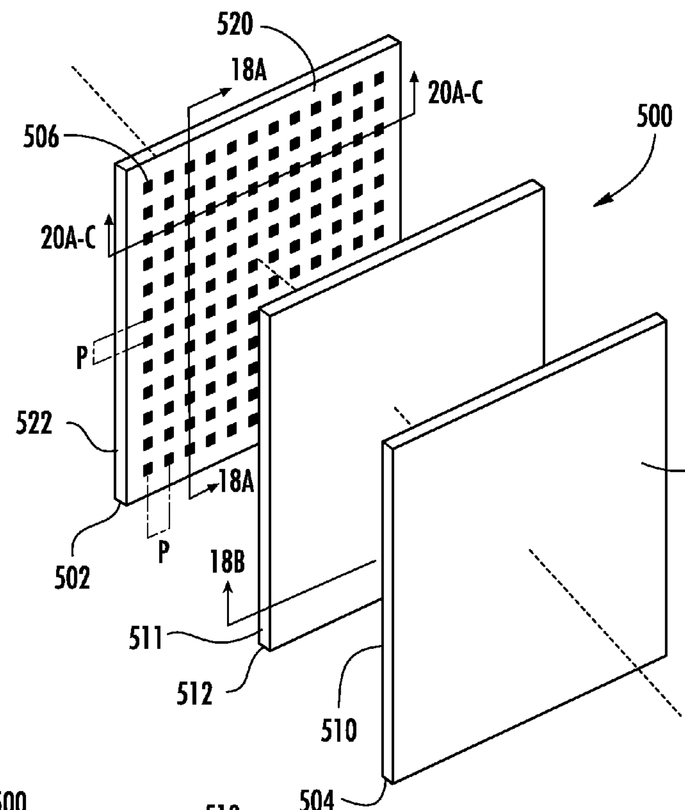

FIG. 17

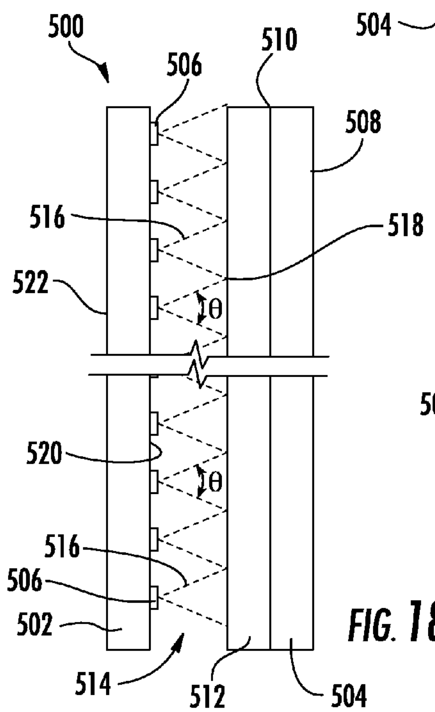

FIG. 18A

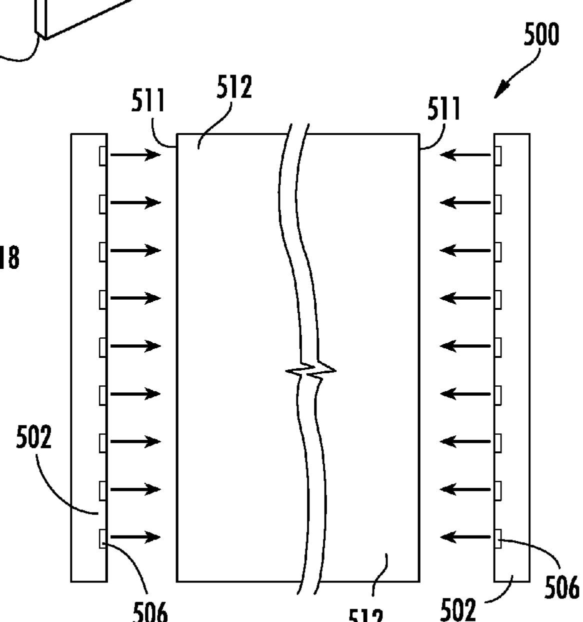

FIG. 18B

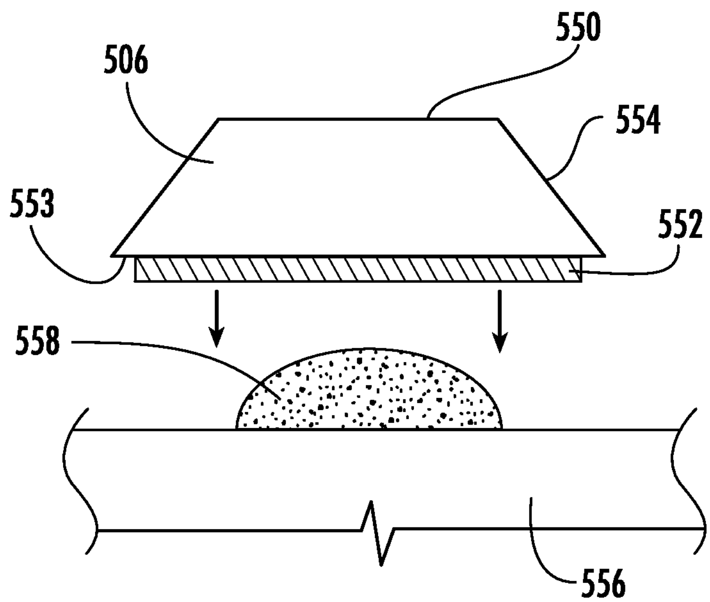

FIG. 19A

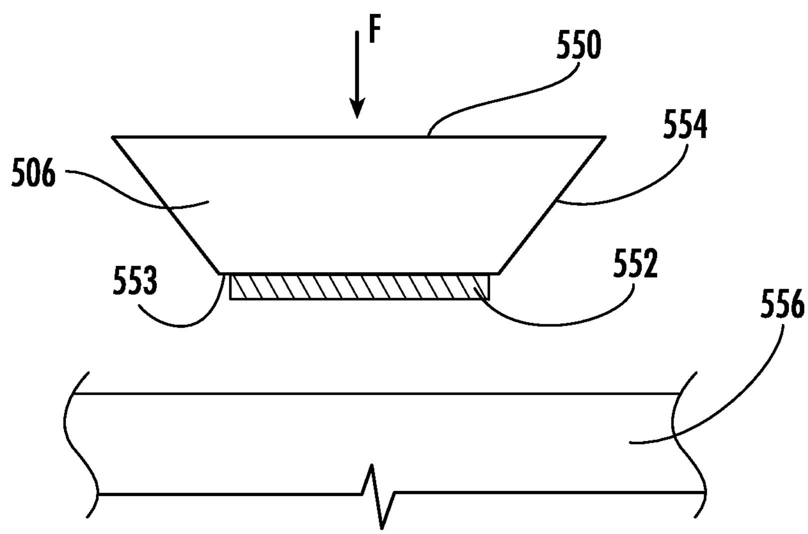

FIG. 19B

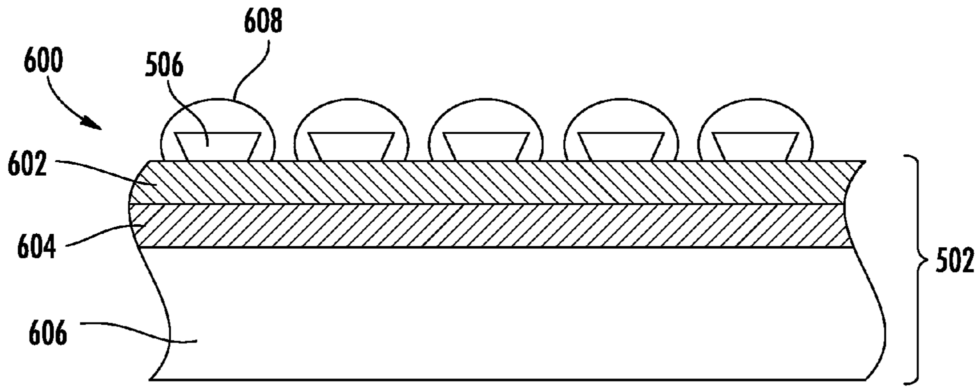

FIG. 20A

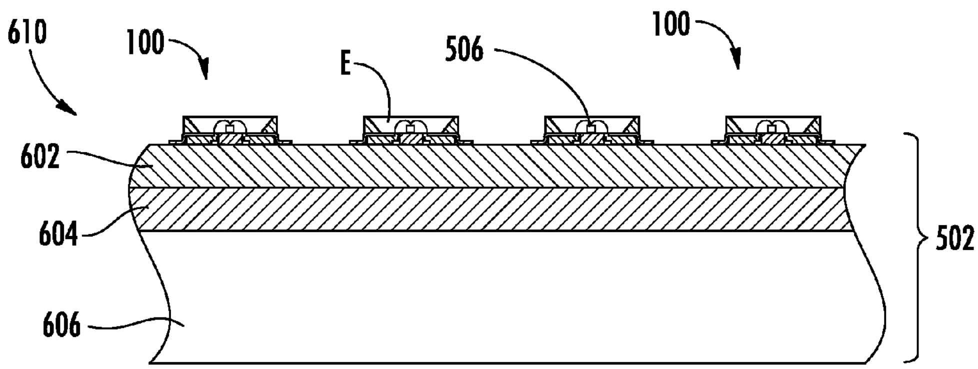

FIG. 20B

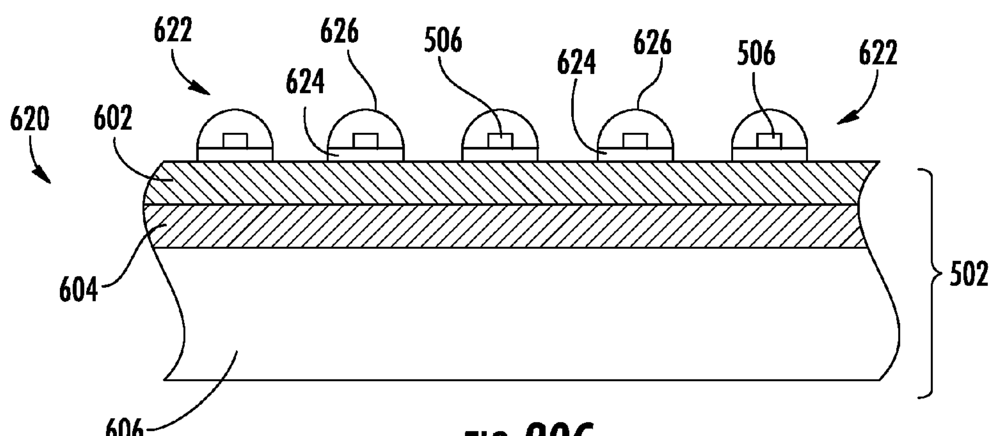

FIG. 20C

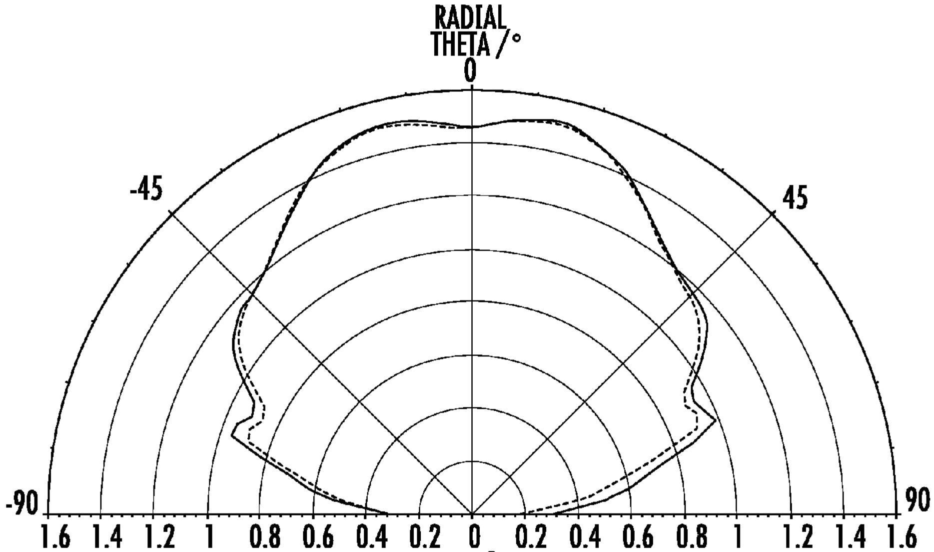

FIG. 21A

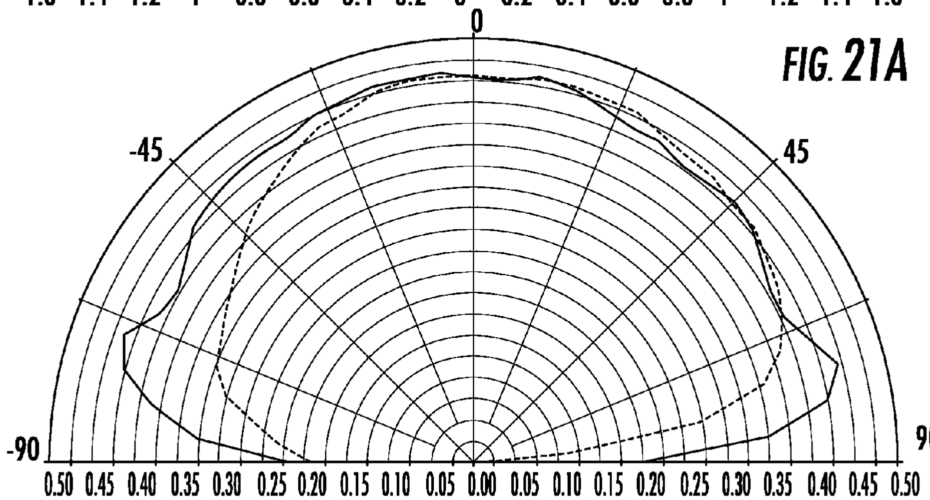

FIG. 21B

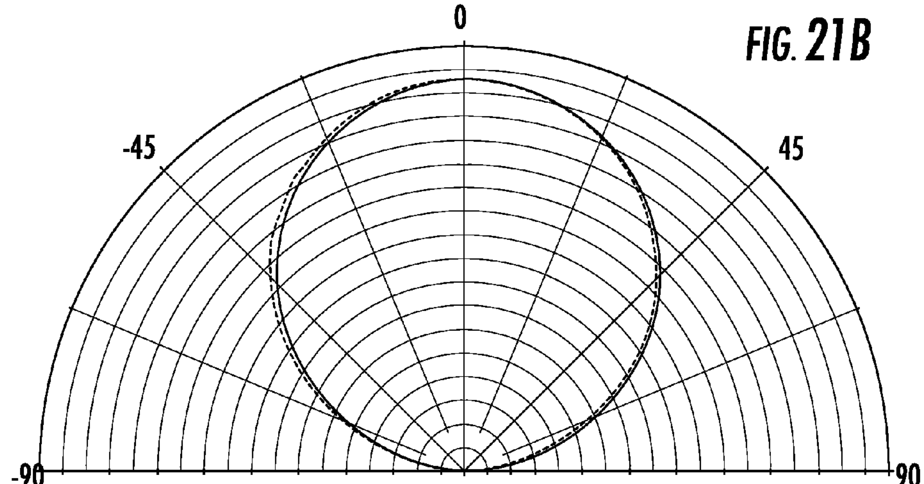

FIG. 21C

LIGHT EMITTING DIODE (LED) DEVICES, SYSTEMS, AND METHODS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of and claims benefit and priority to U.S. Utility patent application Ser. No. 12/969,267, filed Dec. 15, 2010, to U.S. Utility patent application Ser. No. 12/479,318, filed Jun. 5, 2009, and to U.S. Design patent application Ser. No. 29/353,652, filed Jan. 12, 2010, the entire contents of which are incorporated by reference herein.

TECHNICAL FIELD

The subject matter herein relates generally to light emitting diode (LED) devices, systems, and methods. More particularly, the subject matter herein relates to metal to metal die attach for LED devices, systems and methods.

BACKGROUND

Solid state light sources, such as light emitting diodes (LEDs) are widely used in flat display panels for monitors, televisions, and/or other displays. LEDs can be used in the design of thinner, energy-saving backlighting systems for use with liquid crystal display (LCD) devices. Backlighting and/or other display panel systems using LEDs require less power to meet the brightness specifications for backlighting applications, thereby significantly reducing energy consumption and the need for active cooling systems. Conventional backlighting displays typically include an illumination panel wherein one or more LEDs are bonded within component packages, and the packages can then be mounted to the panel. Conventional LED packages used in backlighting systems can comprise LEDs bonded within respective packages using silicone or non-metallic epoxies. LEDs attached in backlighting displays using conventional die attach materials can become at least partially detached from the package during operation or experience squeeze out of the bonding materials. Such defects can lead to light failure and/or thermal breakdown of the LEDs during operation.

Despite the availability of various backlighting and/or display panels in the marketplace, a need remains for more robust metal-to-metal die attach techniques and materials in backlighting for providing optimized die attach with a lower thermal resistance and enhanced reliability.

SUMMARY

The present subject matter relates to light emitting diode (LED) devices, systems, and methods. In one aspect, the subject matter herein relates to die attach used in LED devices, systems, and methods for providing a more robust die attach bond resulting in fewer defects and/or detachment of LEDs, such as for use in backlighting devices and systems.

It is, therefore, an object of the present disclosure to provide improved LED devices, systems, and methods. These and other objects of the present disclosure as can become apparent from the disclosure herein are achieved, at least in whole or in part, by the subject matter described herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view showing top, side, and end portions of a solid state light emission package according to an embodiment of the present subject matter;

FIG. **2** is a perspective view showing bottom, side, and end portions of the solid state light emission package of FIG. **1**;

FIG. **3** is a top plan view of the solid state light emission package of FIGS. **1-2**;

FIG. **4** is a side elevation view of the solid state light emission package of FIGS. **1-3**;

FIG. **5** is a bottom plan view of the solid state light emission package of FIGS. **1-4**;

FIG. **6** is an end elevation view of the solid state light emission package of FIGS. **1-5**;

FIG. **7** is a top plan view of a package subassembly prior to complete fabrication of the solid state light emission package of FIGS. **1-6**;

FIG. **8**A is a simplified schematic cross-sectional view of a body portion of the package subassembly of FIG. **7**, illustrating the angle of a side wall or end wall portion thereof;

FIG. **8**B is a simplified schematic cross-sectional view of a body portion of the package subassembly of FIG. **7**, illustrating the angle of a transition wall portion thereof;

FIG. **9** is a side cross-sectional view of the subassembly of FIG. **7**;

FIG. **10** is a perspective view showing top, side, and end portions of a leadframe and thermal transfer material of the solid state light emission package of FIGS. **1-6** and the package subassembly of FIG. **7-8**;

FIG. **11** is a side elevation view of the leadframe and thermal transfer material of FIG. **10**;

FIG. **12**A is a cross-sectional schematic view of a thermal transfer material according to one embodiment and useable with a solid state light emission package as disclosed herein;

FIG. **12**B is a cross-sectional schematic view of a thermal transfer material according to another embodiment and useable with a solid state light emission package as disclosed herein;

FIG. **12**C is a cross-sectional view of a portion of a solid state light emission package according to one embodiment of the present subject matter, showing a thermal transfer material similar to the embodiment illustrated in FIG. **12**A;

FIG. **13** is a top plan view of a solid state light emission package according to another embodiment of the present subject matter, the package lacking encapsulant in the reflector cavity for clarity of illustration;

FIG. **14**A is a top plan view of a solid state light emission package similar to the package of FIG. **13**, but including encapsulant in the reflector cavity;

FIG. **14**B is a perspective view showing top, side, and end portions of the solid state light emission package of FIG. **14**A;

FIGS. **15**A and **15**B illustrate a side view of a solid state emitting device and a light emission package according to the present subject matter;

FIGS. **16**A and **16**B graphically illustrate measured and extrapolated long-term L70 lifetime values at two different ambient temperatures (T_a);

FIG. **17** illustrates a backlighting system according to the present subject matter;

FIGS. **18**A and **18**B illustrate side views of a backlighting system according to the present subject matter;

FIGS. **19**A and **19**B illustrate side views of die attach of a solid state emitting device used in backlighting systems according to the present subject matter;

FIGS. **20**A to **20**C illustrate side views of an illumination panel used in a backlighting system according to the present subject matter; and

FIGS. **21**A to **21**C illustrate radiation patterns of solid state devices used in the backlighting systems according to the present subject matter.

DETAILED DESCRIPTION

The present subject matter now will be described more fully hereinafter with reference to the accompanying drawings, in which embodiments of the subject matter are shown. The present subject matter may, however, be embodied in many different forms and should not be construed as limited to the specific embodiments set forth herein. Rather, these embodiments are provided to convey the scope of the subject matter to those skilled in the art. In the drawings, the size and relative sizes of layers and regions may be exaggerated for clarity.

It will be understood that when an element such as a layer, region or substrate is referred to as being "on" or extending "onto" another element, it can be directly on or extend directly onto the other element or intervening elements may also be present. In contrast, when an element is referred to as being "directly on" or extending "directly onto" another element, no intervening elements are present. It will also be understood that when an element is referred to as being "connected" or "coupled" to another element, it can be directly connected or coupled to the other element or intervening elements may be present. In contrast, when an element is referred to as being "directly connected" or "directly coupled" to another element, no intervening elements are present.

It will be understood that although the terms "first" and "second" are used herein to describe various regions, layers and/or portions, these regions, layers and/or portions should not be limited by these terms. These terms are only used to distinguish one region, layer or portion from another region, layer or portion. Thus, a first region, layer or portion discussed below could be termed a second region, layer or portion, and similarly, a second region, layer or portion may be termed a first region, layer or portion without departing from the teachings of the present subject matter.

Furthermore, relative terms, such as "lower" or "bottom" and "upper" or "top," may be used herein to describe relationship of one or more elements to other elements as illustrated in the Figures. It will be understood that relative terms are intended to encompass different orientations of the device in addition to the orientation depicted in the figures. For example, if a device in the figures is turned over, elements described as being on the "lower" side of other elements would then be oriented on "upper" sides of the other elements. The exemplary term "lower," can therefore, encompasses both an orientation of "lower" and "upper," depending of the particular orientation of the figure. Similarly, if the device in one of the figures is turned over, elements described as "below" or "beneath" other elements would then be oriented "above" the other elements. The terms "below" or "beneath" can therefore encompass both an orientation of above and below.

Unless otherwise defined, terms (including technical and scientific terms) used herein should be construed to have the same meaning as commonly understood by one of ordinary skill in the art to which this subject matter belongs. It will be further understood that terms used herein should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art, and should not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

As used herein, the terms solid state light emitter or solid state light emitting device may include a light emitting diode (LED), laser diode and/or other semiconductor device which includes one or more semiconductor layers, which may include silicon, silicon carbide, gallium nitride and/or other semiconductor materials, a substrate which may include sapphire, silicon, silicon carbide and/or other microelectronic substrates, and one or more contact layers which may include metal and/or other conductive materials. The terms solid state emitter and LED are used interchangeably throughout the application.

Solid state light emitting devices according to embodiments of the subject matter may include III-V nitride (e.g., gallium nitride) based LEDs or lasers fabricated on a silicon carbide substrate, such as those devices manufactured and sold by Cree, Inc. of Durham, N.C. Such LEDs and/or lasers may be configured to operate such that light emission occurs through the substrate in a so-called "flip chip" orientation.

Light emitting devices according to embodiments described herein may comprise group III-V nitride (e.g., gallium nitride) based light emitting diodes (LEDs) or lasers fabricated on a growth substrate, for example, silicon carbide substrate, such as those devices manufactured and sold by Cree, Inc. of Durham, N.C. For example, Silicon carbide (SiC) substrates/layers discussed herein may be 4H polytype silicon carbide substrates/layers. Other silicon carbide candidate polytypes, such as 3C, 6H, and 15R polytypes, however, may be used. Appropriate SiC substrates are available from Cree, Inc., of Durham, N.C., the assignee of the present subject matter, and the methods for producing such substrates are set forth in the scientific literature as well as in a number of commonly assigned U.S. patents, including but not limited to U.S. Pat. No. Re. 34,861; U.S. Pat. No. 4,946,547; and U.S. Pat. No. 5,200,022, the disclosures of which are incorporated by reference herein in their entireties.

As used herein, the term "Group III nitride" refers to those semiconducting compounds formed between nitrogen and one or more elements in Group. III of the periodic table, usually aluminum (Al), gallium (Ga), and indium (In). The term also refers to binary, ternary, and quaternary compounds such as GaN, AlGaN and AlInGaN. The Group III elements can combine with nitrogen to form binary (e.g., GaN), ternary (e.g., AlGaN), and quaternary (e.g., AlInGaN) compounds. These compounds may have empirical formulas in which one mole of nitrogen is combined with a total of one mole of the Group III elements. Accordingly, formulas such as AlxGa1-xN where $1>x>0$ are often used to describe these compounds. Techniques for epitaxial growth of Group III nitrides have become reasonably well developed and reported in the appropriate scientific literature, and in commonly assigned U.S. Pat. No. 5,210,051, U.S. Pat. No. 5,393,993, and U.S. Pat. No. 5,523,589, the disclosures of which are hereby incorporated by reference herein in their entireties.

Although various embodiments of LEDs disclosed herein comprise a growth substrate, it will be understood by those skilled in the art that the crystalline epitaxial growth substrate on which the epitaxial layers comprising an LED are grown may be removed, and the freestanding epitaxial layers may be mounted on a substitute carrier substrate or submount which may have better thermal, electrical, structural and/or optical characteristics than the original substrate. The subject matter described herein is not limited to structures having crystalline epitaxial growth substrates and may be used in connection with structures in which the epitaxial layers have been removed from their original growth substrates and bonded to substitute carrier substrates.

Group III nitride based LEDs according to some embodiments of the present subject matter, for example, may be fabricated on growth substrates (such as a silicon carbide substrates) to provide horizontal devices (with both electrical contacts on a same side of the LED) or vertical devices (with electrical contacts on opposite sides of the LED). Moreover, the growth substrate may be maintained on the LED after fabrication or removed (e.g., by etching, grinding, polishing, etc.). The growth substrate may be removed, for example, to reduce a thickness of the resulting LED and/or to reduce a forward voltage through a vertical LED. A horizontal device (with or without the growth substrate), for example, may be flip chip bonded to a carrier substrate or printed circuit board (PCB), or wire bonded. A vertical device (without or without the growth substrate) may have a first terminal bonded to a carrier substrate, mounting pad, or PCB and a second terminal wire bonded to the carrier substrate, electrical element, or PCB. Examples of vertical and horizontal LED chip structures are discussed by way of example in U.S. Publication No. 2008/0258130 to Bergmann et al. and in U.S. Publication No. 2006/0186418 to Edmond et al., the disclosures of which are hereby incorporated by reference herein in their entireties.

The LED can be coated, at least partially, with one or more phosphors with the phosphors absorbing at least a portion of the LED light and emitting a different wavelength of light such that the LED emits a combination of light from the LED and the phosphor. In one embodiment, the LED emits a white light combination of LED and phosphor light. The LED can be coated and fabricated using many different methods, with one suitable method being described in U.S. patent application Ser. Nos. 11/656,759 and 11/899,790, both entitled "Wafer Level Phosphor Coating Method and Devices Fabricated Utilizing Method", and both of which are incorporated herein by reference. In the alternative, LEDs can be coated using other methods such an electrophoretic deposition (EPD), with a suitable EPD method described in U.S. patent application Ser. No. 11/473,089 entitled "Close Loop Electrophoretic Deposition of Semiconductor Devices", which is also incorporated herein by reference. It is understood that LED devices and methods according to the present subject matter can also have multiple LEDs of different colors, one or more of which may be white emitting.

Solid state light emitters may be used individually or in combinations, optionally together with one or more luminescent materials (e.g., phosphors, scintillators, lumiphoric inks) and/or filters, to generate light of desired perceived colors (including combinations of colors that may be perceived as white). Inclusion of luminescent (also called lumiphoric) materials in LED devices may be accomplished by adding such materials to encapsulants, adding such materials to lenses, or by direct coating onto LEDs. Other materials, such as dispersers and/or index matching materials may be included in such encapsulants.

Referring now to FIGS. **1-6**, a solid state light emitter package **100** according to certain embodiments of the present subject matter can comprise a body structure **10** defining a body cavity (preferably reflective to constitute a reflector cavity) **20** containing six solid state emitters **12**A-**12**F. Each emitter **12**A-**12**F is arranged over (i.e., on or adjacent to) the upper surface **71** of a thermal transfer material **70** disposed along the floor of the reflector cavity **20**, and each emitter **12**A-**12**F is disposed in electrical communication with a first electrical lead **51** and a second electrical lead **61** using wirebonds **31**, **32**. In one aspect, each emitter **12**A-**12**F can be electrically connected in parallel as shown. An optional arrangement comprises at least a first emitter of **12**A-**12**F can be electrically connected in series with at least one other of the emitters **12**A-**12**F. In other aspects, emitters **12**A-**12**F can be electrically connected to each other using a combination of series and parallel arrangements. In one embodiment, the emitters **12**A-**12**F may be mounted on an optional submount (not shown) arranged between the emitters **12**A-**12**F and the thermal transfer material **70**. In one aspect, the emitters **12**A-**12**F comprise LEDs. The thermal transfer material **70** can be separated from (and preferably electrically isolated from) each of the electrical leads **51**, **52** via body portions **19**A, **19**B, and can be adapted to conduct heat away from the emitters **12**A-**12**F to a lower surface **72** of the thermal transfer material **70** for dissipation therefrom. In one aspect, thermal transfer material **71** comprises a heatsink directing heat away from the one or more LEDs and to an external source such as, for example, a printed circuit board (PCB) or a metal core printed circuit board (MCPCB). An electrostatic discharge protection device **9** (e.g., a zener diode, or alternatively, a ceramic capacitor, transient voltage suppression (TVS) diode, multilayer varistor, and/or Schottky diode) arranged on the first electrical lead **51** and having an associated wirebond **33** is also disposed in electrical communication with the emitters **12**A-**12**F. The electrical leads **51**, **61** can extend through exterior side walls **15**, **16** disposed at opposing ends of the body structure **10**, with lead tab portions **56**, **66** extending away from the exterior side walls **15**, **16** in a direction outward from a center portion of the package **100**, to enable the lead tab portions **56**, **66** to be soldered or otherwise connected to a current source and sink (not shown) to permit operation of the emitters **12**A-**12**F.

The body structure **10** can comprise an upper face **11**, lower face **13**, and exterior side walls **15-18**. The upper face **11** defines a corner notch **1**, and the lower face **13** can comprise a recess **2** containing the thermal transfer material **70**, with a lower surface **72** and lower protrusion **72**A of the thermal transfer material **70** being exposed. In one embodiment, the body structure **10** has a length and a width (e.g., as represented by exterior side walls **15-18**) that are substantially equal, such that the body structure **10** has a square-shaped footprint. In another embodiments, the length and width of the body structure **10** may be unequal, with the body structure having a rectangular footprint, or the body structure **10** may be formed in other shapes (e.g., round), including footprints conforming to regular polygonal shapes (e.g., octagonal), or footprints of other shapes not constituting regular polygons. The body structure **10** is preferably formed around a leadframe **50** (defining electrical leads **51**, **61**) and the thermal transfer material **70** (as illustrated in FIG. **6**), with the body structure **10** encasing at least a portion of the leadframe **50** and arranged to retain the thermal transfer material **70**. Protruding portions **73**, **74** of the thermal transfer material **70** may be exposed along side walls **17**, **18** of the body structure **10**. The body structure **10** may be advantageously formed using a molding process, such as injection molding, using a thermoplastic and/or thermoset material that is preferably electrically insulating. Polymer-containing materials can be used to form the body structure **10**, with such materials optionally being reinforced (e.g., with fibers, ceramics, or composites). The body structure may be white or light in color to minimize dark appearance of the package **100**. Ceramic and/or composite materials may be utilized in place of polymers to form the body structure **10** in certain embodiments. As an alternative to injection molding, other types of molding and/or forming processes (e.g., sintering) may be used. The body structure **10** may comprise an upper portion **10**A and lower portion **10**B (e.g., as may be formed in upper and lower molding die portions (not shown), respectively). The reflector cavity **20** may be formed as the inverse of a central protrusion in an upper molding die.

Referring to FIGS. **3** and **7**, the reflector cavity **20** is bounded from below by a floor (including portions of the contacts **51**, **61**, body portions **19**A, **19**B, and an upper surface **71** of the thermal transfer material **70**), and bounded along edges by side wall portions **21**A, **21**B, end wall portions **22**A, 22B, and transition wall portions 24A-24D. A transition wall portion 24A-24D is disposed between each respective side wall portion 21A, 21B and end wall portion 22A, 22B. Each side wall portion 21A, 21B and each end wall portion 22A, 22B preferably comprises a substantially straight upper edge, and each transition wall portion 24A-24D preferably comprises a curved or segmented upper edge transitioning from the upper edge of a side wall portion 21A, 21B to the upper edge of an end wall portion 22A, 22B. Each transition wall portion 24A-24D is preferably inclined at a larger average angle, relative to a plane perpendicular to the floor of the reflector cavity, than each side wall portion 21A, 21B and each end wall portion 22A, 22B. For example, FIG. 8A provides a simplified schematic cross-sectional view of a body portion, illustrating the angle θ of a side wall portion or end wall portion thereof relative to a plane perpendicular to the floor of the body cavity. Similarly, FIG. 8B provides a simplified schematic cross-sectional view of a body portion, illustrating the angle ϕ of a transition wall portion relative to a plane perpendicular to the floor of the body cavity. In one embodiment, each side wall portion and each end wall portion is inclined at an angle θ of at least about 20 degrees; more preferably at least about 30 degrees; still more preferably at least about 40 degrees. In further embodiments, the angle θ may be at least about 45 degrees, or at least about 50 degrees. In one each transition wall portion is inclined at an angle ϕ of at least about 30 degrees; more preferably at least about 40 degrees; still more preferably at least about 50 degrees. In further embodiments, the angle ϕ may be at least about 55 degrees, or at least about 60 degrees. Such angles of the side wall portions 21A, 21B, end wall portions 22A, 22B, and transition wall portions 24A, 24D are greater than typically employed in solid state emitter devices. Although the side wall/end wall portions and transition wall portions are illustrated in FIGS. 8A-8B as being angular from the floor of the cavity to the upper edge of the package, in an alternative embodiment any one or more (or all) of these wall portions may be characterized by a segmented and/or curved cross-section, that is, with the wall extending from the floor to the upper edge of the package being non-linear along at least a portion thereof. If such walls are curved or segmented, then the inclination angles mentioned above may correspond to an average angle of a curved or segmented wall, or an angle between endpoints of such a wall. Use of side wall portions 21A, 21B/end wall portions 22A, 22B and transition wall portions 24A-24D of alternating angles enables frontal area of the reflector cavity 20 maximized relative to the square-shaped upper surface 11, while providing desirably diffuse output beam characteristics, particularly when multiple emitters are disposed in the cavity 20.

As indicated previously, the body structure 10 is preferably formed around the leadframe 50 and thermal transfer material 70. Referring to FIGS. 10-11, the leadframe 50 can comprise a first electrical lead 51 and a second electrical lead 61. Each electrical lead 51, 61 can comprise a medial end 58, 68, and a lead tab portion 56, 66 extending away from a center of the emitter package and terminating at a distal end 59, 69. Each electrical lead 51, 61 defines at least one aperture 52, 62 that serves to separate multiple electrical lead segments 51A-51B, 61A-62B. In one embodiment, each electrical lead 51, 61 may comprise multiple apertures serving to separate more than two (e.g., three or more) electrical lead segments. A portion of each aperture 52, 62 is preferably filled with body material of the body structure, with another portion of each aperture 52, 62 being disposed outside the side walls 15, 16 of the body structure 10, such that individual electrical lead segments 51A-51B, 61A-61B are separated from corresponding electrical lead segments 51A-51B, 61A-61B by the apertures 52, 62 along exterior side walls 15, 16 of the body structure 10. Each electrical lead 51, 61 can comprise a first bend 53, 63, a bent portion 54, 64 (that is preferably substantially perpendicular to a plane extending through the medial ends 58, 68), and a second bend 55, 65 transitioning to each electrical lead tab portion 56, 66. Each aperture 52, 62 preferably extends at least into each first bend 53, 63. Each aperture 52, 62 provides multiple benefits. First, a medial portion of each aperture 52, 62 is filled with body material, and thus serves to promote secure retention of the electrical leads 51, 61 within the body structure 10. Second, each aperture 52, 62 serves to reduce the amount of lead material (e.g., metal) subject to being bent to form the first bend 53, 63. This reduces the amount of bending force required to form the first bend 53, 63, as is particularly desirable when the first bend 53, 63 is formed in each electrical lead 51, 61 after formation of the body structure 10 around the electrical leads 51, 61. Bending is preferably performed sufficiently to position at least a portion of each electrical lead 51, 61 in the recesses 5, 6.

Continuing to refer to FIGS. 10-11, the thermal transfer material 70 can comprise an upper surface 71, a lower surface 72 including a downwardly-extending central protrusion 72A. The thermal transfer material 70 defines upper protrusions 73, 74 along ends of the upper surface 71, with such upper protrusions 73, 74 extending through side walls of the body structure 10 (as illustrated in FIGS. 1, 2, and 4) and being exposed along tips thereof. Side walls 75 of the thermal transfer material 70 further define protrusions 76, 77 that promote secure retention of the thermal transfer material 70 by the body structure 20 (as illustrated in FIG. 9), and also reduces potential for leakage (e.g., of flux or solder during manufacture of the emitter package 100, or of encapsulant (not shown) disposed in the cavity 20 during operation of the emitter package 100) along interfaces between the body structure 10 and the thermal transfer material 70. Such protrusions 76, 77 along side walls 75 of the thermal transfer material 70 may be varied in number, size, shape, and orientation (e.g. angled upward or downward).

The leadframe 50 may be stamped from a first flat sheet of metal or other conductive material. The thermal transfer material 70 may be stamped from a second flat sheet of metal or other conductive material, with the second sheet preferably being thicker than the first sheet to enable the resulting thermal transfer material 70 to have a substantially greater average thickness than the electrical leads 51, 61. Relative to an average thickness of the electrical leads 51, 61, an average thickness of the thermal transfer material 70 is preferably at least two times as thick, and more preferably at least about 2.5 times as thick. A multitude of leadframes may be defined in a single first sheet, and a multitude of thermal transfer materials may be defined in a second sheet, and body structure material may be formed around such first and second sheets to simultaneously form a multitude of emitter package subassemblies (e.g., such as the individual subassembly shown in FIGS. 8-9). Bends 53, 54, 63, 64 may be defined in electrical leads 51, 61 of each package subassembly after formation of the body structure. The multitude of emitter package subassemblies may be separated into individual package subassemblies by cutting adjacent to side walls 17, 18 and distal ends 59, 69 of the lead tab portions 56, 66. Such cutting exposes tips of the thermal transfer material protrusions 73, 74 along side walls 17, 18 of each emitter package 100.

Referring to FIGS. 2, 4, and 5, recesses 5, 6 are preferably defined in exterior side walls 15, 16 of the body structure 10 adjacent to (e.g., below) locations where the leads 51, 61 extend through the exterior side walls 15, 16. Such recesses 5, 6 are preferably arranged to receive the bent portion (or at least part of the thickness of the bent portion) of each electrical lead **51**, **61**. Each recess **5**, **6** has a depth relative to the corresponding exterior side wall **15**, **16**, with the depth of each recess **5**, **6** preferably being at least as large as an average thickness of the electrical leads **51**, **61**. The recesses **5**, **6** provide multiple benefits. First, the recesses **5**, **6** eliminate presence of material immediately disposed below the first bends **53**, **63**, thereby reducing stress applied to the body structure **10** when the first bends **53**, **63** are formed after the leadframe **50** (including electrical leads **51**, **61**) is retained in the body structure **10**. Second, the recesses **5**, **6** enable each first bend **53**, **63** to have a tighter bending radius and reduce or eliminate outward extension of the bent portions **54**, **64** (preferably substantially perpendicular to the lower body surface **13** and the electrical lead tab portions **56**, **66**) relative to the side walls **15**, **16**, thereby reducing the effective footprint of the light emission package **100**. Reduction of effective footprint of emitter packages **100** enables such packages **100** to be mounted at higher density on an underlying substrate (not shown), and optionally overlaid with a Lambertian reflector or diffuser having reduced hole spacing (e.g., within a backlit display device, such as a liquid crystal display (LCD)), thereby enhancing lighting performance such as by enabling higher flux density and/or greater lighting uniformity.

Referring to FIG. **12**A, in one embodiment a thermal transfer material **170** for integration and use with a solid state emitter package (e.g., package **100**) may comprise an upper surface **171**, a lower surface **172**, a lower protruding portion **172**A, and curved lateral protrusions **176**, **177** extending outward from side walls **175**. A photograph showing a cross-section of a thermal transfer material with similarly curved lateral protrusions is shown in FIG. **12**C. Referring to FIG. **12**B, in another embodiment a thermal transfer material **270** may comprise an upper surface **271**, a lower surface **272**, a lower protruding portion **272**A, and upwardly-angled lateral protrusions **276**, **277** extending outward and upward from side walls **275**. Downwardly-angled lateral protrusions may be employed in a similar embodiment (not shown). Any combinations of the foregoing lateral protrusions may be employed. Lateral protrusions may be formed by any suitable manufacturing method, including stamping, extrusion, milling, and the like. In further embodiments, the lateral protrusions may be replaced with, or supplemented by, recesses (not shown) in side walls of a thermal transfer material to provide similar sealing utility, with such recesses being formable by similar methods.

FIG. **13** shows a top plan view photograph of a solid state emitter package **300** similar to the package **100** described hereinabove. To promote ease of viewing, such package **300** is devoid of encapsulant, diffuser, and/or lens material (as otherwise may be retained in the cavity to cover and/or protect the emitters and wirebonds, and to optionally interact with light emitted by the emitters), but it is to be understood that emitter packages as disclosed herein may desirably comprise encapsulant, diffuser and/or lens material, optionally including at least one lumiphor to interact with light emitted by the emitters and responsively emit light of a different wavelength. The package **300** according to the present embodiment differs from the package **100** according to a prior embodiment with respect to layout of the wirebonds (e.g., the wirebond of the electrostatic discharge device may extend to a second contact, rather than contacting a wirebond for an emitter), and with respect to size of the apertures defined in the electrical leads. As compared to the apertures **52**, **62** defined in the electrical leads **51**, **61**, the apertures shown in FIG. **13** are larger.

FIGS. **14**A-**14**B depict a solid state light emission package **300**A similar to the package **300** depicted in FIG. **13**, but the package **300**A can comprise encapsulant material **399** disposed within the cavity containing the emitters, and the wirebond arrangement in the package **300** differs from wirebond arrangements shown in prior embodiments.

As discussed previously, body structure **10** can comprise a white plastic material, more specifically, a molded white plastic material. In one aspect, body structure **10** can comprise any suitable moldable material. In another aspect, body structure **10** can comprise a plastic material having quantitative and qualitative properties optimized for solid state device package applications. The plastic material can in one aspect comprise, for example, any suitable organic polymer, such as for example a heat resistant resin such as a polyamide resin. The plastic material can be filled with glass or mineral material for strength and something like titanium dioxide for reflectivity.

Utilizing a plastic material such as described herein for body structure **10** of, for example, package **100** allows for an advantageous softness for body structure **10** at operating temperatures as hardness can depend upon temperature. This softness allows body structure **10** to desirably have improved reliability and useful lifetime. The plastic material can in one aspect be a liquid crystal polymer (LCP). An optimized plastic material in accordance herewith can comprise a glass transition temperature (T_g) that can, for example, be greater than approximately 110 degrees Celsius (° C.). The glass transition temperature (T_g) can, for example, be greater than approximately 115° C. or greater than approximately 120° C. In one aspect, the glass transition temperature (T_g) can be greater than approximately 123° C. The optimized plastic material in accordance herewith can also comprise a melting point temperature (T_m) that can be less than approximately 315° C. The melting point temperature (T_m) can, for example, be less than approximately 310° C. The melting point temperature (T_m) can, for example, be less than approximately 300° C. In one aspect, the melting point temperature (T_m) can be approximately 307° C. A plastic material with a T_g of approximately 123° C. is higher than many plastics conventionally used and can allow the package to have increased stability at elevated temperatures. A plastic material with a lower T_m of approximately 307° C. can allow better flowability because the melting temperature is lower than that of plastics conventionally used and the plastic body is easier to mold. The plastic selected for body structure **10** can also comprise optimized qualitative properties. For example, a white plastic material can be chosen which exhibits a better reflectivity retention value while also exhibiting fewer tendencies to discolor, degrade, and/or yellow when subjected to heat and/or light exposure. The reflectivity of the plastic material can in one aspect be greater than 90% for example, and that level or another level of high reflectivity can be maintained over time, heat, moisture, and blue light exposure.

Other characteristics or features of the plastic material for body structure **10** can comprise an elongation value (mechanical property) of approximately 1.4% or greater, or an elongation value of 1.6% or greater. In one aspect, the elongation value can be approximately 1.5% or greater. Also as a mechanical property, the flexural strength of the plastic material of body structure **10** as measured by ASTM D790 standards can be approximately 150 MPa or lower, approximately 130 MPa or lower, or approximately 120 MPa or lower. In one aspect, the flexural strength of the plastic material of body structure **10** can be approximately 140 MPa or lower as measured by ASTM D790 standards. Also as a mechanical property, the flexural modulus of the plastic material of body structure **10** can be approximately 6.9 GPa or lower, or approximately 6.5 GPa or lower. In one aspect, the flexural modulus of the plastic material of body structure **10** can be approximately 6.0 GPa or lower. As yet another mechanical property, the tensile strength of the plastic material of body structure **10** can be approximately 100 MPa or lower as measured by ASTM D638 standards, approximately 90 MPa or lower, or approximately 80 MPa or lower. In one aspect, the tensile strength of the plastic material of body structure **10** can be less than approximately 75 MPa as measured by ASTM D638 standards.

FIGS. **15**A and **15**B illustrate side views of a solid state emitter generally designated **12** as it may be positioned for mounting over substrate **400**. Substrate **400** can comprise any suitable metallic material and can comprise any substrate within an emitter package, such as package **100** (FIG. **1**). For example, substrate **400** can comprise thermal transfer material **70** or any layer otherwise deposited over thermal transfer material **70**. Solid state emitter **12** can comprise any size, shape, dimension, and/or structure of, for example, a LED chip. FIG. **15**A illustrates an example of a metal-to-metal die attach. FIG. **15**B illustrates another example of a metal-to-metal die attach. Metal-to-metal die attach refers to attaching or bonding of one or more metals of the emitter to substrate **400** disposed within an emitter package. For example, the metals which can attach during metal-to-metal die attach techniques can comprise at least two of (i) a layer of metal on the backside of solid state emitter **12**, (ii) metallic substrate **400** within emitter package **100** over which the emitter will become mounted, and/or (iii) a metal assist material disposed between the emitter **12** and substrate **400**. Substrate **400** can comprise any suitable metal such as, but not limited to, silver (Ag) or platinum (Pt).

FIGS. **15**A and **15**B illustrate solid state emitter **12** comprising an upper surface **402** and a bonding surface **403**. Solid state emitter **12** can comprise a horizontally structured device or a vertically structured device as previously described. Upper surface **402** of solid state emitter **12** can comprise one or more bondpads disposed thereon for wirebonding to electrical elements, for example, first and second electrical leads (FIG. **1**). In one aspect, solid state emitter **12** can comprise a vertically structured device wherein upper surface **402** can comprise a single bondpad. In another aspect, solid state emitter **12** can comprise a horizontally structured device wherein upper surface **402** can comprise two bondpads. In a further aspect, solid state emitter **12** can comprise a horizontally structured device wherein each of the p and n-sides electrically communicate with substrate **400** such that upper surface **402** does not require bondpads. Bonding surface **403** of solid state emitter **12** can comprise a portion of the p-side, n-side, or each of the p and n-sides of an LED device. In one aspect, the emitter can be connected to substrate **400** at an insulating side of the LED device. In one aspect, the emitter can be connected to a substrate **400** at a portion of the growth substrate or carrier substrate of the LED such as previously discussed.

FIGS. **15**A and **15**B illustrate the bonding surface **403** of solid state emitter **12** as comprising a backside metal pad or bonding layer **404** for mounting over substrate **400**. Bonding layer **404** can extend the full length and/or surface area of bonding surface **403** or any suitable portion thereof. Solid state emitter **12** can comprise lateral sides **406** which can extend between upper surface **402** and bonding surface **403**. FIGS. **15**A and **15**B illustrate inclined lateral sides **406**, however, lateral sides **406** can be substantially vertical or straight where a straight-cut emitter is selected. FIG. **15**A illustrates upper surface **402** having a greater surface area than the surface area of bonding surface **403**. FIG. **15**B illustrates upper surface **402** having a smaller surface area than the surface area of bonding surface **403**. In some aspects, bonding surface **403** and upper surface **402** comprise the same surface area. As noted earlier, solid state emitters **12** can comprise a square, rectangle, or any suitable shape in addition to having any suitable lateral side configuration.

Any suitable die attach method can be used to mount solid state emitter **12** within a LED package, for example, over substrate **400**. In one aspect, any suitable optimized die attach method and/or materials can be used. For example, optimized die attach methods can comprise metal-to-metal die attach methods for facilitating attachment of one or more metals on and/or between the solid state emitter **12** and substrate **400**. FIG. **15**A illustrates an example of a metal-to-metal die attach method which can be eutectic or non-eutectic. This metal-to-metal die attach method can comprise using an attach material **408** to facilitate the metal-to-metal die attach. In one aspect, a flux-assisted eutectic metal-to-metal die attach method can be used and in other aspects a metal-assisted non-eutectic metal-to-metal die attach method can be used. In a flux-assisted eutectic, or flux eutectic, die attach method, bonding layer **404** can comprise a metal alloy having a eutectic temperature, for example, but not limited to, an alloy of gold (Au) and tin (Sn). For example, bonding layer **404** can comprise an 80/20 Au/Sn alloy having a eutectic temperature of approximately 280° C. In the flux eutectic technique, attach material **408** can comprise a flux material. In the non-eutectic technique, attachment material **408** can comprise a metallic material. The flux material can serve as a conduit for facilitating the metal-to-metal die attach between the bonding layer **404** and substrate **400** when the bonding layer **404** is heated above the eutectic temperature. The metal of bonding layer **404** can flow into and attach to the metal of substrate **400**. The metal of bonding layer **404** or can atomically diffuse and bond with atoms of the underlying mounting substrate **400**. In one aspect, flux used in a flux-assisted eutectic method can comprise a composition, for example, 55-65% rosin and 25-35% polyglycol ether in addition to small amounts of other components. Any suitable flux material can be used however.

One consideration when choosing a material for use in flux-assisted eutectic die attach can be the melting point T_m of the solid state chip bonding layer **404**. A flux chosen for use can be liquid at room temperature or can require heating or melting to reach a melting point T_m. In one aspect, the body structure of a package in which an emitter will be attached can comprise a plastic material having a melting point within approximately 28° C. or less of the eutectic temperature of the bonding layer. In one aspect, at least one LED can be mounted over the substrate **400** at a mounting temperature of approximately 280° C. or greater. Body structure **10** can comprise a plastic material with a melting point of approximately 28° C. or less from the mounting temperature at which the at least one LED is mounted or attached. The melting point can be approximately 25° C. or less from the mounting temperature at which the at least one LED is mounted or attached, approximately 20° C. or less from the mounting temperature at which the at least one LED is mounted or attached, or even approximately 10° C. or less from the mounting temperature at which the at least one LED is mounted or attached. Using flux-assisted eutectic die attach in such a package is unexpected based upon this small temperature difference and the possibility that the plastic may begin to be adversely affected during the die attach process.

Flux-assisted eutectic die attach methods can be tedious, and it is unexpected to use such methods when attaching solid state emitters within a molded plastic package body or for backlighting applications or situations. The flux eutectic die attach according to the present subject matter can utilize dispensing flux assist material **408**, that can be liquid at room temperature, in an amount to be precisely the right volume to avoid either swimming of the emitter chips or poor die attach if too much or too little flux is used. Flux-assisted eutectic die attach according to the present subject matter can also require the right composition for each of the flux assist material **408** and bonding metal **404** of the emitter chips. Flux-assisted eutectic die attach according to the present subject matter can optimally utilize a very clean and flat surface and substrates that do not move or bend during heating and cooling such to stress the solder joint. Flux-assisted eutectic according to the present subject matter can utilize a fine surface roughness that is small enough not to encumber the Au/Sn bonding surface of the emitter chips while being rough enough to allow flux to escape during heating. The heating profile can be matched perfectly to the bonding metal **404**, such as Au or AuSn, to ensure a good weld between the bonding metal **404** and underlying substrate **400**. Using flux-assisted eutectic for die attach according to the present subject matter also can utilize an inert atmosphere, such as a nitrogen atmosphere, to reduce oxygen gas (O_2) levels and also allow gravity to apply a downward force on the emitter **12**. This can reduce the amount of oxidation at the metal-to-metal bond between bonding layer **404** and underlying substrate **400**.

Flux-assisted eutectic die attach can comprise several process techniques, for example, using a heated collet for dispensing the flux material **408**, heating the substrate and/or entire LED package, forming a gas, and applying pressure to the LED to the underlying mounting substrate. Methods can also comprise using a heated collet in combination with heating the mounting substrate and/or entire LED package and applying pressure. Body structure **10** can be heated quickly using microwave, laser, conduction and/or excitation fields, etc. all which can be done quickly and in an inert atmosphere allowing the body structure **10** to attain at least the eutectic temperature of the Au/Sn bonding metal on the LED solid state emitter (at least approximately 280° C.). Heating thereby facilitates adequate metal-to-metal bonding between the bonding layer **404** of emitter chips and underlying mounting substrate **400**. In one aspect, sonic scrubbing or thermosonic scrubbing techniques can also be used, as the friction of the scrubbing step can generate the heat required for metal-to-metal bonding. Flux-assisted eutectic die attach methods can also comprise plasma cleaning in an inert atmosphere before and/or after flux eutectic die attach.

Still referring to FIG. **15**A, a non-eutectic metal-to-metal die attach method can be used which can also comprise an assist material **408**, the assist material **408** can comprise a metallic material. In this aspect, bonding layer **404** can comprise a single metal or a metal alloy. For example, bonding layer **404** can comprise Au, Sn, or AuSn. In non-eutectic methods, the bonding layer does not need to reach or exceed a temperature, for example, a eutectic temperature. In this aspect, assist material **408** can comprise a metallic material to facilitate the metal-to-metal bonding. For example, assist material **408** can comprise AuSn paste or Ag epoxy. Any suitable metallic assist material **408** can be used. The metal of bonding layer **404** can attach to the metal of the assist material **408**. The metal of the assist material **408** can also attach to the metal of substrate **400**. In one aspect, a metal "sandwich" forms between bonding layer **404**, assist material **408**, and substrate **400** in non-eutectic metal-to-metal attach techniques where a metallic assist material **408** is used. Metal-assisted, non-eutectic die attach can be tedious, just as flux-assisted methods, and it is also unexpected to use such methods when attaching solid state emitters within a molded plastic package body or for backlighting applications or situations. Metal-to-metal attachment using an assist material **408** can be hard to control and tedious when attaching multiple emitters within a package having a plastic body. Heating the package to the appropriate temperature such that assist material **408** can facilitate metal-to-metal die attach can be hard to achieve in plastic packages, for example, packages comprising optimized plastic.

FIG. **15**B illustrates a metal-to-metal die attach technique which does not require an assist material **408**. One such method can comprise a thermal compression die attach method wherein the metal of bonding layer **404** will directly attach to the metal of substrate **400**. The thermal compression method can be eutectic or non-eutectic. In one aspect, thermal compression can be used when bonding layer **404** comprises an alloy having a eutectic temperature. In other aspects, bonding layer **404** can comprise a metal not having a eutectic temperature. Substrate **400** can comprise any suitable metal, not limited to Ag or Pt. In one aspect, bonding layer **404** comprises any suitable metal. In one aspect, bonding layer **404** can comprise a layer of Sn having any suitable thickness. In one aspect, bonding layer **404** can comprise a thickness greater than approximately 0 μm. In one aspect, bonding layer **404** can comprise a bonding layer equal to or greater than at least approximately 0.5 μm. In one aspect, bonding layer **404** can comprise a layer of Sn having a thickness of at least equal to or greater than approximately 2.0 μm. Unlike the flux-assisted eutectic or metal-assisted non-eutectic methods just described, thermal compression metal-to-metal die attach techniques can utilize an external downward force F as illustrated in FIG. **15**B. Force F can comprise a compression delivered in a heated environment, thus deemed a thermal compression, as opposed to dispensing a flux or metallic assist material **408**. The thermal compression technique is an alternative die attach method developed to reduce metal squeeze out of the bonding layer **408** which can form Shottky or Shunt defects and allow subsequent leakage of current and other various and related problems. In one aspect, the bonding temperature in thermal compression techniques can be approximately 255-265° C. after subjecting substrate **400** to a pre-heat treatment or process. The substrate can be heated to a mounting temperature of at least 20° C. above the melting temperature of the bonding layer **404**. The bonding time can be approximately 300 msec and the bonding force can be approximately 50+/−10 grams (g). Predetermined settings can be important for this method, including adequate preheat, bonding temperature, bonding time, and bonding force. The equipment and predetermined settings for use with thermal compression methods can be difficult to use and/or maintain, and it is unexpected to use such methods when attaching solid state emitters within a molded plastic package body or for backlighting applications or situations.

Although metal-to-metal methods have previously been used in solid state device packages comprising ceramic substrates and package bodies (in non-backlighting situations), it is not known and is unexpected to use flux-assisted eutectic, metal-assisted non-eutectic, or thermal compression die attach techniques for device packages having molded plastic bodies. It is also not known and is unexpected to use flux-assisted eutectic, metal-assisted non-eutectic, and/or thermal compression attach techniques in LED backlighting situations as described further herein. It is also quite unexpected to use flux-assisted, metal-assisted, or thermal compression die attach techniques with molded plastic body structure **10** having optimized plastic material that can have, for example, a

T_m of approximately 307° C. Light packages having emitters utilizing metal-to-metal die attach methods as described herein can, for example and without limitation, offer light output of up to 122 lumens at 300 mA in cool white (CW), and up to 100 lumens at 300 mA in warm white (WW) color points. For example, LED packages disclosed herein can be used in lighting fixtures offering a minimum CRI for CW color points of 65 CRI. LED packages disclosed herein can be used in lighting fixtures offering a minimum CRI for CW color points of 75 CRI which corresponds to a range of 5,000 K to 8,300 K CCT. LED packages disclosed herein can also offer, for example, a minimum CRI for WW color points of 80 CRI which corresponds to a range of 2,600K to 3,700K CCT. Such LED packages can be used for both standard and high voltage configurations.

FIGS. **16**A and **16**B illustrate predicted long term white L70 lifetime values which can be expected using solid state device packages comprising, for example, optimized plastic and/or metal-to-metal die attach methods and materials in accordance herewith. The metal-to-metal die attach method can comprise one of the flux-assisted eutectic, metal-assisted non-eutectic, or thermal compression methods described in FIGS. **15**A and **15**B. Lumen Maintenance life (L_{XX}) values represent the elapsed operating time over which the solid state lighting devices will maintain the percentage, XX %, of its initial light output. For example, L70 equals the time to 70% lumen maintenance in hours, that is, L70 equals the time to maintain 70% of its initial light output in hours. FIG. **16**A illustrates the predicted mean white L70 lifetime measured and extrapolated at an ambient air temperature (T_a) of 55° C. FIG. **16**B illustrates the predicted mean white L70 lifetime measured and extrapolated at T_a of 85° C. The values represented by the white squares were measured at a current of 350 mA for 6,000 hours and then extrapolated to 70% using the ENERGY STAR exponential method fit to the last data point. The values represented by the black squares were measured at a current of 1000 mA for 6,000 and extrapolated to 70% using the same ENERGY STAR method fit to the last data point. In FIG. **16**B, values represented by the black circle were measured at a current of 500 mA for 6,000 hours and then extrapolated to 70% using the ENERGY STAR method fit to the last data point. According to the measured data and extrapolations above, the L70 lifetime for the packages described herein can be approximately 150,000 hours or greater at 350 mA at 55° C. Table 1.0 below comprises interpolated values of data for 55° C. as illustrated in FIG. **16**A, and the interpolated values are designated by an asterisk (*).

TABLE 1.0

Current (mA)	Ta (° C.)	L70 (hours)
350	55	150,696
400	55	140,508*
500	55	122,151*
600	55	106,193*
700	55	92,320*
800	55	80,259*
900	55	69,774*
1000	55	60,659

The light emission package according to the present subject matter can therefore be operable to emit light with an output of approximately 70% or greater of an initial light output for at least approximately 150,000 hours or more. That is, under normal operating conditions, the packages disclosed herein can provide L70 lifetime of over 150,000 hours, or 17 years, using ENERGY STAR lifetime prediction methods. Similarly and according to the data and extrapolations above, the L70 lifetime for the packages described herein can be approximately 61,000 hours at 350 mA at 85° C.

Table 2.0 below comprises interpolated values of data for 85° C. as illustrated in FIG. **16**B, and the interpolated values are designated by an asterisk (*).

TABLE 2.0

Current (mA)	Ta (° C.)	L70 (hours)
350	85	61,143
400	85	55,602*
500	85	45,980*
600	85	38,024*
700	85	31,444*
800	85	26,003*
900	85	21,503*
1000	85	17,782

One or more solid state emitter packages as described herein may be integrated into lighting apparatuses of varying types, including LCD devices and backlighting systems as described below. In one embodiment, an enclosure comprises an enclosed space and at least one solid state emitter package or lighting device as disclosed herein, wherein upon supply of current to a power line, the at least one lighting device illuminates at least one portion of the enclosed space. In another embodiment, a structure comprises a surface and at least one solid state emitter package or lighting device as disclosed herein, wherein upon supply of current to a power line, the lighting device illuminates at least one portion of the surface. In another embodiment, a solid state emitter package or lighting device as disclosed herein may be used to illuminate an area comprising at least one of the following: a swimming pool, a room, a warehouse, an indicator, a road, a vehicle, a road sign, a billboard, a ship, a toy, an electronic device, a household or industrial appliance, a boat, and aircraft, a stadium, a tree, a window, a yard, and a lamppost. In further embodiments, the solid state emitter package or lighting device as disclosed herein may be used for direct light, indirect light, backlighting applications, and/or lighting fixtures.

Backlighting With Optimized Metal-to-Metal Die Attach

FIG. **17** illustrates an expanded perspective view of a representative flat display panel system, generally designated **500**. Embodiments described and illustrated herein can provide uniform backlighting for small or large area display panels greater or less than a dimension of 17" diagonal. Display panel system **500** can be combined with other electrical and/or mechanical elements to provide computer monitors, televisions, and/or other flat display panels. As used herein, "uniform" backlighting means than an ordinary viewer who views the display at a conventional viewing distance is not aware of any discrepancy or variation in backlighting intensity. In some embodiments, variations of less than about 25% can provide uniform intensity, whereas, in other embodiments variations of less than 5% can provide uniform intensity. Display panel system **500** can comprise square, rectangle, or any suitable shaped panels of any suitable dimension. Embodiments of display panels described herein can provide direct backlighting of flat panel LCDs.

FIG. **17** illustrates display panel system **500** comprising an illumination panel **502** and a display panel, or LCD panel **504**. Illumination panel **502** can comprise a plurality of solid state emitters, or LEDs **506**. In one aspect, illumination panel **502** can comprise a planar (i.e., two dimensional) array of LEDs **506** mounted either directly over illumination panel **502** or arranged in packages over illumination panel **502**. LEDs **506** can be spaced apart from one another at a predetermined distance, or pitch P so as to provide substantially uniform backlighting of LCD panel **504**. LEDs **506** can be packed in a random array, a grid array (as shown), a staggered array, or any suitable array. Uniform and/or non-uniform packing may be provided. Pitch P between adjacent LEDs **506** can allow for uniform backlighting of at least a portion of LCD panel **504**. In one aspect, LEDs **506** can provide uniform backlighting over the entire LCD panel **504**. A frame (not shown) can be disposed about illumination panel **502** and LCD panel **504** to hold the panels adjacent and either together or spaced apart with a gap disposed therebetween.

LCD panel **504** can comprise a flat display panel having planar array of LCD devices, or cells. In one aspect, LCD panel **504** can comprise a planar array of liquid crystal devices arranged into a matrix of pixels (not shown). An image can form on a front display surface **508** of LCD panel **504** when the liquid crystal devices are subjected to backlight illumination. To provide backlight illumination to LCD panel **504**, the planar array of LEDs **506** comprising illumination panel **502** can be arranged into a matrix such that each LED **506** is arranged to provide illumination to a single LCD device or to a plurality of LCD devices thereby collectively defining specific images on display surface **508**. Backlight LEDs **506** can be arranged to illuminate the entirety or a portion of LCD panel **504**, the illumination passing through LCD panel **504** from a back surface **510** of the panel through the LCD pixels to the display panel **508**. LCD panel **504** can comprise the back surface **510** parallel and opposing front surface **508** and a thickness disposed therebetween defined by the LCD devices, or cells. The thickness of LCD panel **504** can be any suitable dimension.

Optionally, one or more optical layers **512** may be disposed between illumination panel **502** and LCD panel **504**. Optical layer **512** can comprise at least one layer or film such as polarizing films, light scattering films, light guide films or any suitable film capable of manipulating light emitted by illumination panel **502**. In one aspect, optical layer **512** can comprise a diffuser that distributes light uniformly behind the viewing area. In one aspect, optical efficiency may be enhanced by direct backlighting such that the need for diffusing and/or optical films between illumination panel **502** and LCD panel **504** may be reduced or eliminated. In one aspect, optical layer can comprise an edge **511** along which one or more LEDs **506** may direct light. Optionally, the light could be directed along an edge of LCD panel as described in FIG. **18**B.

FIGS. **18**A and **18**B illustrate different cross-sectional views of an unexpanded display panel **500** described and illustrated by FIG. **17**. For illustration purposes, the figures illustrate LEDs **506** directing light toward optical layer **512**, however, the LEDs **506** in each of FIGS. **18**A and **18**B could direct light toward LCD panel **504** instead. That is, in FIG. **18**A optical layer **512** could be excluded, and in FIG. **18**B, optical layer **512** could be replaced with LCD panel **504**. The figures would be the same otherwise to include additional figures would be excessive.

FIG. **18**A illustrates one or more LEDs **506** mounted over illumination panel **502** providing direct backlighting to LCD panel **504**. LEDs **506** can be disposed adjacent each other spaced apart a pitch P in rows, columns, and/or a random array (FIG. **17**). Pitch P can be the same dimension for LEDs **506** spaced apart between the rows and columns of the planar array, or the LEDs can be spaced apart in rows at a first pitch and spaced apart in columns at a second pitch. Alternatively, any suitable pitch P and variations of pitch can be used between the planar array of LEDs **506**. FIG. **18**A illustrates at least one optical layer or film **512** disposed between illumination panel **502** and LCD panel **504**, however, such film is optional. LEDs **506** can provide backlighting directly to LCD panel **504**. In one aspect, the planar array of LED devices **508** can be configured to transmit light directly to the planar array of LCD pixels comprising LCD panel **504** over a space, or gap, generally designated **514**. Gap **514** can be disposed between illumination panel **502** and LCD panel **504**, or optical film **512**, and can define a space across which one or more individual light paths **516** can extend from the one or more LED devices **506**. In one aspect, light paths **516** can extend perpendicular to the planar array of LEDs **506** and perpendicular to LCD panel **504**. In other aspects, lights paths **516** can extend from an edge parallel LCD panel **504** or be reflected perpendicular LCD panel **504**. That is, in some aspects, at least some of the LEDs **506** can be disposed within a periphery of the LCD panel **504**.

Still referring to FIG. **18**A and in one aspect, each LED device **506** comprising the planar array of LEDs can emit light at an illumination angle θ that can conform to radiation patterns such as those described in FIGS. **21**A to **21**C. The edges of adjacent light paths **516** can just meet at a periphery **518**, or slightly overlap depending on the pitch P at which adjacent LEDs **506** are spaced. When one or more LEDs **506** are spaced at the pitch P shown, adjacent light paths **516** can intersect, or touch, at periphery edges **518**. If spaced closer together, individual light paths **516** can overlap. Different grids or arrangements of planar arrays of LEDs **506** can also affect the overlap and distribution of light paths **516**. In one aspect, light paths **516** can intersect at periphery edges **518** and/or overlap to provide uniform backlighting illumination to LCD panel **504**. FIG. **18** illustrates at least one column of the planar array of LEDs **506**. Light paths **516** from respective LEDs **506** in adjacent columns and/or rows can intersect and/or overlap. LEDs **506** can also be configured for indirect backlighting of LCD panel **504**, for example, LEDs **506** can be disposed around edges of illumination panel and indirectly reflect and illuminate LCD panel **504**.

FIG. **18**A further illustrates illumination panel **502** comprising a first surface **520** over which the one or more LEDs **506** can mount. Illumination panel **502** can comprise a second surface **522** parallel and opposing first surface **520**. First surface **520** of illumination panel **502** can face optical film **512**. In one aspect, first surface **520** of illumination panel **502** can face back surface **510** of LCD panel **504**. Illumination panel **502** can comprise any suitable substrate over or onto which LEDs **506** may be mounted. For example, LCD panel **502** can comprise a circuit, printed circuit board (PCB), metal core printed circuit board (MCPCB) or any other suitable substrate. Top surface **520** of illumination panel **502** can comprise an electrically and/or thermally conductive surface. In one aspect, top surface **520** can comprise a metallic surface over which the one or more LEDs **506** can mount. In another aspect, top surface **520** can comprise a planar array of metallic surfaces over which the planar array of LEDs **506** can mount. One or more conductive traces (not shown) can connect the planar array of metallic surfaces such that electrical current or signal can flow to each of LEDs **506**.

FIG. **18**B illustrates another embodiment of panel display system **500**. In this system, the arrows indicate light being directed from the one or more LEDs **506** toward opposing side edges **511** of optical layer **512**. Optionally, the light can be directed toward an edge of LCD panel **504**. This embodiment comprises an edge lighting panel display system where the one or more LEDs direct light towards edges, rather than directly behind, the panels of panel display system **500**. LEDs **506** can be arranged in any suitable manner, such as in an array, and can be in any suitable LED package or outside of a package. LEDs **506** can be connected, to a structure that can be positioned directly against and in contact with side edges **511** or can be spaced apart from side edges **511**. As shown in FIG. **18**B, LEDs **506** are shown spaced apart for illustration purposes only.

FIGS. **19**A and **19**B illustrate examples of metal-to-metal die attach methods used in backlighting applications according to the disclosure herein and not heretofore known. Such methods can comprise flux eutectic (e.g., flux-assisted eutectic), thermal compression, and non-eutectic metal-to-metal die attach (e.g., metal-assisted non-eutectic) methods. Notably, it is unexpected to use metal-to-metal die attach techniques in solid state device packages having molded plastic bodies. It is equally as unexpected to use such die attach methods or materials in backlighting applications and/or systems. This is at least partly due to both the cost and/or specialized equipment required to perform the metal-to-metal attach techniques. It is also unexpected because of the large number of LEDs **506** comprising the planar array formed over illumination panel **502**. Metal-to-metal die attach methods can be tedious and require inert atmospheres in addition to accurate control of the amount of assist material dispensed and accurate heating profiles. It is not known and quite unexpected to use such metal-to-metal die attach methods in backlighting situations such as when attaching large quantities of LEDs. The metal-to-metal attachment methods can require dispensing just the right amount and type of assist material, for example, flux, and require precise control of reflow temperature profiles, and/or require thermal compression, all of which can be difficult to achieve when attempting to attach LEDs in a repeatable fashion in mass production. In this regard, consistency and repeatability are necessary to achieve long-lifetime results. If conditions are not correct, voiding in the metal die attach, or bonding layer can be too high, leading to encapsulation defects and/or high thermal resistance. Further, an incorrect reflow profile or atmosphere can lead to LED degradation. These difficulties are true regardless of LED or package size or geometry, with each case providing unique assembly problems. For example, small LED chips with correspondingly small die attach areas can have low voiding but weak die attach strength due in part to incomplete metal reflow. Conversely, large LED chips with correspondingly high die attach area can have high die shear strength but high voiding. Both are unsuitable for long-lifetime applications.

A robust substrate-to-source die attach process can be important to achieve low electrical resistance, low thermal resistance and good mechanical and electrical integrity. In one aspect, an illumination source, or LED, can comprise a metal die attach area and a substrate can comprise a metallic layer. Thus, the bond therebetween can be described as a metal-to-metal bond facilitated by a suitable die attach method. Metal die attach area can comprise, for example, an area of a metallic bonding layer disposed on a surface of the LED. A first metal-to-metal die attach method illustrated by FIG. **19** comprises an assisted (e.g., using flux, metal, or otherwise) eutectic or non-eutectic die attach method which can be used in backlighting applications. This method can be performed without application of an external force during the die attach process. One advantage of this method is that no squeeze-out of the die attach metal, or bonding layer, occurs. This can reduce the risk of forming a Schottky contact to the n-substrate of the device. Another robust meta-to-metal die attach method which can be used for backlighting applications comprises a thermal compression die attach method is used during the bonding process rather than an attach material. The advantage is similar in that that substantially little to no squeeze-out of the die attach metal occurs. In addition, no residue is left from the attach material, such as a flux or metal assist material. Even no-clean flux materials can leave behind a small portion of residue which may subsequently need cleaned with alcohol or other suitable solvent. In addition, the metal-to-metal bond formed when the bonding layer attaches over the external substrate can comprise a lower thermal resistance allowing the LED to resist detachment from the substrate over its operating lifetime.

FIGS. **19**A and **19**B are similar to FIGS. **15**A and **15**B, and the description of FIGS. **15**A and **15**B are equally applicable to FIGS. **19**A and **19**B as illustrated. LED **506** of FIG. **19** can comprise any size, shape, dimension, and/or structuring of LED. For example, LED **506** can comprise a substantially beveled design as illustrated in FIGS. **19**A and **19**B or it can comprise a straight-cut design. LED **506** can be vertically or horizontally structured such that zero, one, or greater than one bondpad is disposed on an upper surface **550** of the LED for electrically connecting to one or more electrical elements. LED **506** can be mounted such that the p-side, n-side, or each of p and n-sides of the LED are mounted over an external substrate, for example substrate **556**. In one aspect, the LED **506** can be connected to a substrate **556** at a portion of the growth substrate or carrier substrate of the LED **506** such as previously discussed. FIGS. **19**A and **19**B illustrate LED **506** comprising the upper surface **550** opposite a bonding surface **553**. Bonding surface **553** can comprise a die attach area comprising an area of bonding layer **552**. In one aspect, upper surface **550** can comprise a smaller dimensional length and/or width than bonding layer **552**. In one aspect, upper surface **550** can comprise a smaller surface area than a surface area of bonding layer **552**. Lateral sides **554** can incline or slope between the upper surface **550** and bonding surface **553**. In one aspect, bonding layer **552** can comprise any suitable metallic alloy not limited to Au, Sn, or metal alloy, for example, 80/20 Au/Sn as described earlier. In one aspect, bonding layer **552** can comprise a layer of Sn having any suitable thickness. In one aspect, bonding layer **552** can comprise a layer of Sn having a thickness greater than approximately 0 μm. In one aspect, bonding layer **552** can comprise a bonding layer equal to or greater than at least approximately 0.5 μm. In one aspect, bonding **552** can comprise a layer of Sn having a thickness of at least equal to or greater than approximately 2.0 μm.

FIGS. **19**A and **19**B further illustrates LED **506** mounted over a substrate **556**. Substrate **556** can comprise a surface or layer of illumination panel **502** or a substrate **400** (FIGS. **15**A, **15**B) within an LED package, for example, thermal transfer material **70** within package **100** previously described. FIG. **19**A illustrates a metal-to-metal die attach method utilizing an assist material **558** for facilitating the metal-to-metal bond. In one aspect, the metal-to-metal die attach method can comprise a eutectic or non-eutectic die attach method. In one aspect, a flux-assisted eutectic die attach method is used. In other aspects, a metal-assisted non-eutectic die attach method is used. Where a eutectic method is chosen, bonding layer **552** can comprise a metal alloy having a eutectic temperature which can attach to a metallic substrate **556**. In one aspect, bonding layer **552** comprises 80/20 Au/Sn and attach material **558** can comprise an amount of flux material which can be dispensed over substrate **556**. LED **506** can then be attached and/or mounted to substrate **556** upon appropriate heating of the bonding layer **552** to its eutectic temperature such that metallic atoms within the bonding layer atomically diffuse into metallic atoms of substrate **556**. In one aspect, reflow heating techniques are used, the technique having distinct time and temperature profiles. As noted earlier a consideration when choosing a material for use in flux-assisted eutectic die attach can be the melting point T_m of the LED bonding layer **552**. A flux chosen for use can be liquid at room temperature or can require heating or melting to reach a melting point T_m. Any suitable size or type of chip can be attached using metal-to-metal techniques and/or materials described herein. For example, LED **506** can be attached such that the active, light-emitting layer is junction down or junction up. In one aspect, LED **506** can comprise a flip chip LED design.

Still referring to FIG. **19**A, a non-eutectic metal-to-metal die attach method can be used which can also comprise an assist material **558**, the assist material **558** comprising a metal or metallic material. In this aspect, bonding layer **552** can comprise a single metal or a metal alloy. For example, bonding layer **552** can comprise Au, Sn, or AuSn. In non-eutectic methods, the bonding layer does not need to reach or exceed a temperature, for example, a eutectic temperature. In this aspect, assist material **558** can comprise a metallic material to facilitate the metal-to-metal bonding. For example, assist material **558** can comprise AuSn paste or Ag epoxy. Any suitable metallic assist material **558** can be used. The metal of bonding layer **552** can attach to the metal of the assist material **558**. The metal of the assist material **558** can also attach to the metal of substrate **556**, for example an illumination panel **502** or LED package. In one aspect, a metal "sandwich" forms between bonding layer **552**, assist material **558**, and substrate **556** in non-eutectic metal-to-metal attach techniques where a metallic assist material **558** is used. Metal-assisted non-eutectic die attach methods can be tedious as flux-assisted methods, thus, it is also unexpected to use such methods when attaching LEDs **506** for backlighting applications. Metal-to-metal attachment using an assist material **558** can be hard to control and tedious when attempting to attach LEDs in a repeatable fashion in mass production over, for example, a backlighting panel. In this regard, it is unexpected to use flux-assisted or metal-assisted metal-to-metal die attach methods for backlighting applications.

Assist material **558** used in eutectic or non-eutectic metal-to-metal die attach methods can be placed using pin transfer or other precision dispense method, and the LED **506** can then be placed downward into the attach material **558**. In one aspect, a no-clean flux assist material **558** can be dispensed onto substrate **556** via pin transfer. In other aspects, a AuSn paste or Ag epoxy metal assist material **558** can be dispensed onto substrate **556**. Careful control of dispense volume of flux and/or metal attach material **558** can be important to minimize risk of movement LED **506** during reflow where a reflow heating techniques is used. For eutectic metal-to-metal techniques and upon placement of LED **506**, substrate **556** can be heated to at least greater than the AuSn eutectic temperature using any suitable heating method to reflow or melt the AuSn metal bonding layer **552**. The type of flux, the amount of flux used, and the reflow time and temperatures are important factors to control to optimize die attach results and for long term reliability of the attached LED. In one aspect, substrate **556** can be heated to a mounting temperature greater than a melting temperature and/or a eutectic temperature of bonding layer **552**. In one aspect, substrate **556** can be heated to a temperature of at least approximately 10° C. or greater than the melting temperature, or eutectic temperature of the bonding layer **552** of LED **506**. In one aspect, substrate **556** can be heated to at least approximately 20° C. or greater than the melting temperature of bonding layer **552**. In addition, LED **506** should be placed through the flux and in contact with the substrate prior to reflow. If too much flux is used, inadequate melting of bonding layer **552** may result which would cause an inadequate bond between LED **506** and underlying substrate **556** having a large number of voids and potentially leading to partial or full detachment of the LED **506** during operation (i.e. illumination). Flux-assisted eutectic die attach can result in a strong, robust die attach between LED **506** and substrate **556**. A stronger bond between LED **506** and substrate **556** with improved die shear strengths are expected. Improved thermal resistance at the bond (i.e., the LED/substrate interface) is also expected, which can allow LED **506** to stay cooler during operation, thereby providing improved color and lumen stability over the operating lifetime.

Defects can occur during die attach of a LED **506** to an external substrate, wherein a conductive path can form from the edge of the silicon-carbide LED substrate to the bonding layer **552** of the LED. The distance between the LED substrate (which can be silicon carbide) and bonding layer **552** can be approximately 5 microns. If residual die bonding layer material (i.e., AuSn) extends up the lateral side **556** and contacts the substrate (e.g., squeeze out) then the LED can form an electrical short and fail to illuminate or it could potentially leak electrical current being less energy efficient and less bright. The flux-assisted and metal-assisted die attach processes can minimize the likelihood of such defects occurring during die attach by minimizing squeeze out of the metal bonding layer **552**. Conventional die attach methods including silicone or non-metallic epoxies can increase the amount of material at the bonding interface and increase the potential for defects caused by squeeze out

Assisted eutectic or non-eutectic and thermal compression metal-to metal die attach methods for die attach according to the present subject matter also can utilize an inert atmosphere, such as a nitrogen atmosphere, to reduce oxygen gas (O_2) levels and also allow gravity to apply a downward force on LED **506**. This can reduce the amount of oxidation at the metal-to-metal bond between bonding layer **552** and underlying substrate **556**.

FIG. **19**B illustrates a metal-to-metal die attach method in a backlighting application wherein an assist material **558** is not utilized. In this method, an external force F can compress LED **506** into substrate **556**, for example an illumination panel used in backlighting. Force F can be delivered in a heated environment thus, this technique can be deemed as a thermal compression technique. Bonding layer **552** can comprise any suitable metal. In one aspect, bonding layer **552** can comprise a substantially Sn bonding layer **552**. Thermal compression can facilitate a metal-to-metal die attach method which can in turn reduce metal squeeze out of the bonding layer **552** which can form Shottky or Shunt defects and allow subsequent leakage of current and other various and related problems. During thermal compression die attach, the substrate can be heated to at mounting temperature of at least greater than approximately the melting temperature of the bonding layer **552**. In one aspect the substrate can be heated to a mounting temperature of at least approximately 10° C. above the melting temperature of the bonding layer. In one aspect, the substrate can be heated to a mounting temperature of at least approximately 20° C. above the melting temperature of the bonding layer **552**. The bonding time can be approximately 300 msec and the bonding force F can comprise approximately 50+/−10 grams (g). Predetermined settings can be important for this method, including adequate preheat, bonding temperature, bonding time, and bonding force. As such, a thermal compression metal-to-metal die attach technique is unexpected in backlighting applications.

LEDs **506** can comprise an arrangement or planar arrays of red, green, and blue LED devices configured to emit light that appears as a pixel of white light in operation. Sizes of red, green, and blue LEDs can be selected to meet a desired brightness and/or intensity balancing level. Any configuration of the red, green, and blue LEDs can be used. LED packages and/or LEDs utilizing metal-to-metal die attach methods as described herein can be used in backlighting systems and any suitable display panel system **500**. For example and without limitation, LED packages and/or LEDs used in backlighting and display panel systems can offer light output of up to 122 lumens at 300 mA in cool white (CW), and up to 100 lumens at 300 mA in warm white (WW) color points. For example, LED packages and/or LEDs disclosed herein can be used in lighting fixtures comprising fixtures used in display panel systems offering a minimum CRI for CW color points of 65 CRI. LED packages and/or LEDs disclosed herein can be used in lighting fixtures comprising fixtures used in display panel systems offering a minimum CRI for CW color points of 75 CRI which corresponds to a range of 5,000 K to 8,300 K CCT. LED packages and/or LEDs disclosed herein for use in display panel systems can also offer, for example, a minimum CRI for WW color points of 80 CRI which corresponds to a range of 2,600K to 3,700K CCT. Such LED packages and/or LEDs can be used for both standard and high voltage configurations.

FIGS. **20**A to **20**C illustrate various configurations for die attach used in backlighting applications. FIG. **20**A illustrates a first configuration **600** in which one or more LEDs **506** can be attached over illumination panel **502**. Illumination panel can comprise a fully integrated, solid electrically and thermally conductive panel, or in the alternative it can comprise one or more layers. In one aspect, illumination panel **502** can comprise a MCPCB having an electrically conductive layer **602** to which LEDs **506** can mount. One or more electrically insulating but thermally conductive layers **604** can be disposed adjacent and under electrically conductive layer **602**. In one aspect, thermally conductive layer **604** comprises a dielectric layer. A core layer **606** can be disposed adjacent and under thermally conductive layer **604**. In one aspect, core layer **606** can comprise a metal core substantially formed wholly of aluminum or copper. FIG. **20**A illustrates LEDs **506** directly mounted over illumination panel **502** which can be referred to as a "chip on board" configuration. A lens or dome **608** can be placed, dispensed, or otherwise formed over LEDs **506** individually or as a group. In one aspect, dome **608** can comprise a layer of encapsulant dispensed over LED, the encapsulant containing one or more phosphors for emitting light of a desired wavelength. LEDs **506** can comprise a beveled design having a bonding layer area that can be smaller than an area of the upper surface or vice versa. Beveled chips may reflect more light than conventional LED chip designs because of the beveled surfaces.

FIG. **20**B illustrates one or more LEDs arranged in packages over illumination panel **502** in a second arrangement or configuration generally designated **610**. At least one LED can be arranged within package, however, multiple LEDs can also be mounted. In one aspect, previously described emitter packages **100** can be arranged over illumination panel **502**. In one aspect, emitter packages **100** can comprise a body structure **10** formed using optimized plastic materials previously described. In another aspect, emitter packages **100** can comprise a body structure **10** formed using any suitable plastic, non-plastic, silicone, or ceramic material. Packages can comprise a cavity as illustrated in FIG. **20**B, or not in a cavity as illustrated in FIG. **20**C. Packages can further comprise a lens, or dome as illustrated in FIG. **20**C or not have a lens as in FIG. **20**B. LEDs **506** can be attached within packages **100** using assisted eutectic or non-eutectic die attach methods, or thermal compression methods described herein. Assisted methods can comprise flux-assisted eutectic die attach and metal-assisted non-eutectic die attach methods. Encapsulant E can be dispensed or otherwise placed in a package **100** to an amount even with the body structure, or to an amount such that a concave or convex surface forms. Encapsulant E can comprise one or more phosphors for emitting light of a desired wavelength.

FIG. **20**C illustrates a third arrangement or configuration **620** wherein a second type of LED package, generally designated **622** that can be disposed over illumination panel **502**. In one aspect, LED package **622** can comprise a plastic, silicone, aluminum, or ceramic body **624** within which an LED **506** can be die attached using a using assisted eutectic or non-eutectic die attach methods, or thermal compression methods described herein. Assisted methods can comprise flux-assisted eutectic die attach and metal-assisted non-eutectic die attach methods. In one aspect, LED package **622** can comprise a dome or lens **626** disposed over each of LED **506** and body **624**. For illustration purposes, two LED packages have been illustrated as disposed over illumination panel **502**. In actuality, any suitable LED package or LED chip may be disposed over illumination panel **502**.

FIGS. **21**A to **21**C illustrate radiation or "far-field" patterns of LEDs **506** comprising a chip-on-board configuration or within packages disposed over illumination panel. FIGS. **21**A and **21**B illustrate radiation patterns of un-encapsulated, or bare LEDs used without a dome or lens. In one aspect, the illumination angle θ illustrated in FIG. **18**A can conform to the patterns illustrated in FIGS. **21**A and **21**B, and can intersect and/or overlap with patterns of adjacent LEDs. In one aspect, the radiation patterns illustrated by FIGS. **21**A and **21**B can comprise a substantially uniform curved path when viewed at less than +/−45 degrees. Radiation patterns can be manipulated by placement of a lens, dome, encapsulant or any other suitable reflective covering over a LED. In one aspect, radiation patterns can be manipulated by lenses and/or domes such as illustrated in FIG. **20**A such that a uniform radiation pattern can be achieved. In one aspect, the uniform radiation pattern illustrated by FIG. **21**C can be achieved by using a lens or dome such that light is substantially uniform about +/−90 degree viewing angles.

While the subject matter has been has been described herein in reference to specific aspects, features and illustrative embodiments of the subject matter, it will be appreciated that the utility of the subject matter is not thus limited, but rather extends to and encompasses numerous other variations, modifications and alternative embodiments, as will suggest themselves to those of ordinary skill in the field of the present subject matter, based on the disclosure herein. Correspondingly, the subject matter as hereinafter claimed is intended to be broadly construed and interpreted, as including all such variations, modifications and alternative embodiments, within the scope of this disclosure.

What is claimed is:

1. A backlighting device for use with a display panel, the backlighting device comprising:

one or more light emitting diodes (LEDs) for backlighting a display panel, the one or more LEDs attached to a substrate by eutectic die attach, by thermal compression die attach, or by non-eutectic metal-to-metal die attach; and

the one or more LEDs comprising an array of LEDs operable for providing substantially uniform illumination to the display panel.

2. The device according to claim 1, wherein eutectic die attach comprises flux eutectic die attach.

3. The device according to claim 1, wherein non-eutectic die attach comprises a metal-assist.

4. The device according to claim 3, wherein the metal-assist comprises AuSn paste or Ag epoxy.

5. The device according to claim 1, wherein the substrate comprises an illumination panel disposed behind the display panel.

6. The device according to claim 1, wherein the substrate comprises a mounting surface within an LED package.

7. The device according to claim 1, wherein the one or more LEDs comprises a substantially vertical side disposed between an upper surface and a bonding surface.

8. The device according to claim 1, wherein the one or more LEDs comprises a beveled side inclined between an upper surface and a bonding surface.

9. The device according to claim 8, wherein the upper surface comprises a first surface area and the bonding surface comprises a second surface area.

10. The device according to claim 9, wherein the first surface area is larger than the second surface area.

11. The device according to claim 9, wherein the first surface area is smaller than the second surface area.

12. The device according to claim 1, wherein the one or more LEDs comprise a plurality of red, green, and blue LEDs.

13. The device according to claim 5, wherein at least one optical layer is disposed between the illumination panel and the LCD panel.

14. The device according to claim 1, wherein a bonding surface of the LEDs attaches to the substrate, the bonding surface comprising a layer of gold/tin (Au/Sn).

15. The device according to claim 14, wherein the bonding surface comprises a layer 80/20 AuSn.

16. The device according to claim 1, wherein a bonding surface of the LEDs attaches to the substrate, the bonding surface comprising a layer of tin (Sn).

17. The device according to claim 16, wherein the bonding surface comprises a layer having a thickness equal to or at least greater than approximately 0.5 μm Sn.

18. A backlighting device for use with a display panel, the backlighting device comprising:

one or more light emitting diodes (LEDs) for backlighting a display panel, the one or more LEDs attached to a substrate at a mounting temperature of approximately 280° Celsius (° C.) or greater;

the one or more LEDs operable for providing substantially uniform illumination to the display panel; and

the device comprising a minimum of approximately 65 CRI for Cool White (CW) color points or a minimum of approximately 80 CRI for Warm White (WW) color points.

19. The device according to claim 18, wherein the one or more LEDs attach to a substrate by eutectic die attach, by thermal compression die attach, or by non-eutectic metal-to-metal die attach.

20. The device according to claim 19, wherein eutectic die attach comprises flux eutectic die attach.

21. The device according to claim 19, wherein non-eutectic die attach comprises a metal-assist.

22. The device according to claim 21, wherein the metal-assist comprises AuSn paste or Ag epoxy.

23. The device according to claim 18, wherein the substrate comprises an illumination panel disposed behind the display panel.

24. The device according to claim 18, wherein the substrate comprises a mounting surface within an LED package.

25. The device according to claim 18, wherein the one or more LEDs comprises an array of LEDs.

26. The device according to claim 18, wherein the one or more LEDs comprises a beveled side inclined between an upper surface and a bonding surface.

27. The device according to claim 18, wherein the one or more LEDs comprises a substantially vertical side disposed between an upper surface and a bonding surface.

28. The device according to claim 26, wherein the upper surface comprises a first surface area and the bonding surface comprises a second surface area.

29. The device according to claim 28, wherein the first surface area is larger than the second surface area.

30. The device according to claim 28, wherein the first surface area is smaller than the second surface area.

31. The device according to claim 18, wherein the one or more LEDs comprise a plurality of red, green, and blue LEDs.

32. The device according to claim 23, wherein at least one optical layer is disposed between the illumination panel and the display panel.

33. The device according to claim 18, wherein a bonding surface of the LEDs attaches to the substrate, the bonding surface comprising a layer of gold/tin (Au/Sn).

34. The device according to claim 33, wherein the bonding surface comprises a layer 80/20 AuSn.

35. The device according to claim 18, wherein a bonding surface of the LEDs attaches to the substrate, the bonding surface comprising a layer of tin (Sn).

36. The device according to claim 35, wherein the bonding surface comprises a layer having a thickness equal to or at least greater than approximately 0.5 μm Sn.

37. A backlighting system comprising:

a display panel for displaying an image;

an illumination panel comprising one or more light emitting diodes (LEDs) attached to a substrate;

the one or more LEDs attached to the substrate by eutectic die attach, thermal compression die attach, or by non-eutectic metal-to-metal die attach;

the one or more LEDs operable for providing substantially uniform illumination to the display panel; and

the system comprising a minimum of approximately 65 CRI for Cool White (CW) color points or a minimum of approximately 80 CRI for Warm White (WW) color points.

38. The system according to claim 37, wherein eutectic die attach comprises flux eutectic die attach.

39. The system according to claim 37, wherein non-eutectic die attach comprises a metal-assist.

40. The system according to claim 39, wherein the metal-assist comprises AuSn paste or Ag epoxy.

41. The system according to claim 37, wherein the substrate comprises the illumination panel.

42. The system according to claim 37, wherein the substrate comprises a mounting surface within an LED package.

43. The system according to claim 41, wherein the illumination panel comprises an array of LEDs.

44. The system according to claim 37, wherein the one or more LEDs comprise a beveled side inclined between an upper surface and a bonding surface.

45. The system according to claim 37, wherein the one or more LEDs comprises a substantially vertical side disposed between an upper surface and a bonding surface.

46. The system according to claim 44, wherein the upper surface comprises a first surface area and the bonding surface comprises a second surface area.

47. The system according to claim 46, wherein the first surface area is larger than the second surface area.

48. The system according to claim **37**, wherein the first surface area is smaller than the second surface area.

49. The system according to claim **37**, wherein the one or more LEDs comprise a plurality of red, green, and blue LEDs.

50. The system according to claim **37**, wherein at least one optical film is disposed between the illumination panel and the display panel.

51. The system according to claim **37**, wherein a bonding surface of the LEDs attaches to the substrate, the bonding surface comprising a layer of gold/tin (Au/Sn).

52. The system according to claim **51**, wherein the bonding surface comprises a layer 80/20 AuSn.

53. The system according to claim **37**, wherein a bonding surface of the LEDs attaches to the substrate, the bonding surface comprising a layer of tin (Sn).

54. The system according to claim **53**, wherein the bonding surface comprises a layer having a thickness equal to or at least greater than approximately 0.5 μm Sn.

55. A backlighting system comprising:

a display panel for displaying an image;

an illumination panel comprising an array of light emitting diodes (LEDs) attached to a substrate;

the array of LEDs attached to the substrate at a mounting temperature greater than a melting temperature of a bonding layer of the LEDs; and

the array of LEDs operable for providing substantially uniform illumination to the display panel.

56. The system according to claim **55**, wherein the array of LEDs is attached to the substrate at a mounting temperature of at least approximately 10° C. or greater than a melting temperature of a bonding layer of the LEDs.

57. The system according to claim **55**, wherein the array of LEDs is attached to the substrate at a mounting temperature of at least approximately 20° C. or greater than a melting temperature of a bonding layer of the LEDs.

58. The system according to claim **55**, wherein the substrate comprises the illumination panel.

59. The system according to claim **55**, wherein the substrate comprises a mounting surface within an LED package.

60. The system according to claim **55**, wherein each LED of the array of LEDs comprises a beveled side inclined between an upper surface and a bonding surface.

61. The system according to claim **55**, wherein each LED of the array of LEDs comprises a substantially vertical side disposed between an upper surface and a bonding surface.

62. The system according to claim **60**, wherein the upper surface comprises a first surface area and the bonding surface comprises a second surface area.

63. The system according to claim **62**, wherein the first surface area is larger than the second surface area.

64. The system according to claim **62**, wherein the first surface area is smaller than the second surface area.

65. The system according to claim **55**, wherein the array of LEDs comprise a plurality of red, green, and blue LEDs.

66. The system according to claim **55**, wherein at least one optical layer is disposed between the illumination panel and the display panel.

67. The system according to claim **55**, wherein a bonding surface of the LEDs attaches to the substrate, the bonding surface comprising a layer of gold/tin (Au/Sn).

68. The system according to claim **67**, wherein the bonding surface comprises a layer 80/20 AuSn.

69. The system according to claim **55**, wherein a bonding surface of the LEDs attaches to the substrate, the bonding surface comprising a layer of tin (Sn).

70. The system according to claim **67**, wherein the bonding surface comprises a layer having a thickness equal to or at least greater than approximately 0.5 μm Sn.

71. A method for backlighting a display panel, the method comprising:

providing a backlighting device comprising:

one or more light emitting diodes (LEDs) for backlighting a display panel, the one or more LEDs attached to a substrate by eutectic die attach, thermal compression die attach, or by non-eutectic metal-to-metal die attach; and

the one or more LEDs operable for providing substantially uniform illumination to the display panel; and

positioning the one or more LEDs with respect to the display panel for providing substantially uniform backlighting illumination to the display panel, wherein positioning the one or more LEDs comprises positioning the LEDs spaced apart a gap from the display panel.

72. The method according to claim **71**, providing a backlighting device comprises the one or more LEDs attached to a substrate by eutectic die attach comprising a flux eutectic die attach.

73. The method according to claim **71**, providing a backlighting device comprises the one or more LEDs attached to a substrate by non-eutectic die attach comprising a metal-assist die attach.

74. The method according to claim **73**, wherein the metal-assist die attach comprises AuSn paste or Ag epoxy.

75. The method of claim **71**, wherein positioning the one or more LEDs comprises positioning the LEDs directly behind the display panel.

76. The method of claim **71**, wherein positioning the one or more LEDs comprises positioning the LEDs about a side edge of the display panel.

77. The method of claim **71**, wherein the one or more LEDs are attached directly to the substrate, and the substrate comprises an illumination panel.

78. The method of claim **71**, wherein the one or more LEDs are attached directly to the substrate, and the substrate comprises an LED package disposed over an illumination panel.

79. A method for backlighting a display panel, the method comprising:

providing a backlighting device comprising:

one or more light emitting diodes (LEDs) for backlighting a display panel, the one or more LEDs attached to a substrate at a mounting temperature of approximately 280° Celsius (° C.) or greater; and

the one or more LEDs operable for providing substantially uniform illumination to the display panel; and

positioning the one or more LEDs with respect to the display panel for providing substantially uniform backlighting illumination to the display panel.

80. The method of claim **79**, wherein positioning the one or more LEDs comprises positioning the LEDs directly behind the display panel.

81. The method of claim **79**, wherein positioning the one or more LEDs comprises positioning the LEDs about an edge of the display panel.

82. The method of claim **79**, wherein positioning the one or more LEDs comprises positioning the LEDs spaced apart by a gap from the display panel.

83. The method of claim **79**, wherein the one or more LEDs are attached directly to the substrate, and the substrate comprises an illumination panel.

84. The method of claim **79**, wherein the one or more LEDs are attached directly to the substrate, and the substrate comprises an LED package disposed over an illumination panel.

85. A method for backlighting a display panel, the method comprising:

providing a backlighting system comprising:

a display panel for displaying an image;

an illumination panel comprising one or more light emitting diodes (LEDs) attached to a substrate;

the one or more LEDs attached to the substrate by eutectic die attach, thermal compression die attach, or by non-eutectic metal-to-metal die attach; and

the one or more LEDs operable for providing substantially uniform illumination to the display panel; and

positioning the one or more LEDs with respect to the display panel for providing substantially uniform backlighting illumination to the display panel.

86. The method of claim 85, wherein positioning the one or more LEDs comprises positioning the LEDs directly behind the display panel.

87. The method of claim 85, wherein positioning the one or more LEDs comprises positioning the LEDs about an edge of the display panel.

88. The method of claim 85, wherein positioning the one or more LEDs comprises positioning the LEDs spaced apart a gap from the display panel.

89. The method of claim 85, wherein the one or more LEDs are attached directly to the substrate, and the substrate comprises an illumination panel.

90. The method of claim 85, wherein the one or more LEDs are attached directly to the substrate, and the substrate comprises an LED package disposed over an illumination panel.

91. The method according to claim 85, providing a backlighting system comprises the one or more LEDs attached to a substrate by eutectic die attach comprising a flux eutectic die attach.

92. The method according to claim 85, providing a backlighting system comprises the one or more LEDs attached to a substrate by non-eutectic die attach comprising a metal-assist die attach.

93. The method according to claim 92, wherein the metal-assist die attach comprises AuSn paste or Ag epoxy.

94. A method for backlighting a display panel, the method comprising:

providing a backlighting system comprising:

a display panel for displaying an image;

an illumination panel comprising one or more light emitting diodes (LEDs) attached to a substrate;

the one or more LEDs attached to the substrate at a mounting temperature greater than a melting temperature of a bonding layer of the LEDs;

the one or more LEDs operable for providing substantially uniform illumination to the display panel; and

positioning the one or more LEDs with respect to the display panel for providing substantially uniform backlighting illumination to the display panel.

95. The method of claim 94, wherein providing a backlighting system comprises the one or more LEDs attached to the substrate at a mounting temperature greater than at least approximately 10° Celsius (° C.).

96. The method of claim 94, wherein providing a backlighting system comprises the one or more LEDs attached to the substrate at a mounting temperature greater than at least approximately 20'Celsius (° C.).

97. The method of claim 94, wherein positioning the one or more LEDs comprises positioning the LEDs directly behind the display panel.

98. The method of claim 94, wherein positioning the one or more LEDs comprises positioning the LEDs about an edge of the display panel.

99. The method of claim 94, wherein positioning the one or more LEDs comprises positioning the LEDs spaced apart by a gap from the display panel.

100. The method of claim 94, wherein the one or more LEDs are attached directly to the substrate, and the substrate comprises an illumination panel.

101. The method of claim 94, wherein the one or more LEDs are attached directly to the substrate, and the substrate comprises an LED package disposed over an illumination panel.

102. The device according to claim 1, comprising a minimum of approximately 65 CRI for Cool White (CW) color points or a minimum of approximately 80 CRI for Warm White (WW) color points.

103. The system according to claim 55, comprising a minimum of approximately 65 CRI for Cool White (CW) color points or a minimum of approximately 80 CRI for Warm White (WW) color points.

104. A light emitting device for a lighting fixture, the light emitting device comprising:

a package for housing one or more light emitting diodes (LEDs);

the one or more LEDs attached to a substrate of the package by eutectic die attach, thermal compression die attach, or by non-eutectic metal-to-metal die attach; and

the light emitting device comprising a minimum of approximately 65 CRI for Cool White (CW) color points or a minimum of approximately 80 CRI for Warm White (WW) color points.

105. The light emitting device of claim 104, wherein the lighting fixture comprises a lighting fixture for a panel display system.

106. The light emitting device of claim 104, wherein the panel display system comprises a backlighting system.

107. The light emitting device of claim 104, wherein the non-eutectic metal-to-metal die attach comprises metal-assisted die attach using gold/tin (Au/Sn) paste or silver (Ag) epoxy.

108. The light emitting device of claim 104, wherein the package comprises a lens.

109. The light emitting device of claim 104, wherein the one or more LEDs comprise at least two LEDs.

110. The light emitting device of claim 104, wherein the one or more LEDs comprise beveled lateral sides.

111. The light emitting device of claim 104, wherein the one or more LEDS comprise straight cut lateral sides.

112. The light emitting device of claim 104, wherein the substrate comprises a thermal transfer element.

113. The light emitting device of claim 104, wherein the one or more LEDs are electrically connected in parallel, in series, or a combination of both.

114. The light emitting device of claim 104, wherein the eutectic die attach comprises flux eutectic die attach.

115. A light emitting device for a lighting fixture, the light emitting device comprising:

a package for housing one or more light emitting diodes (LEDs);

the one or more LEDs comprising a bonding surface disposed opposite an upper surface of the one or more LEDS, an inclined lateral side extending between the bonding surface and the upper surface, and the bonding surface comprising a bonding layer attached to a mounting substrate of the package by eutectic die attach, thermal compression die attach, or by non-eutectic metal-to-metal die attach;

wherein the bonding surface the one or more LEDs comprises at least a portion of a substrate, a p-side, a n-side, or each of the p- and n-sides of the LED.

116. The light emitting device of claim **115**, wherein eutectic die attach comprises flux eutectic die attach.

117. The light emitting device of claim **115**, wherein the non-eutectic metal-to-metal die attach comprises metal-assisted die attach using gold/tin (Au/Sn) paste or silver (Ag) epoxy.

118. The light emitting device of claim **115**, wherein the substrate comprises a growth substrate or a carrier substrate.

119. The light emitting device of claim **115**, wherein the package comprises a lens.

120. The light emitting device of claim **115**, wherein the one or more LEDs comprise at least two LEDs.

121. The light emitting device of claim **111**, where the lateral sides are inclined between the bonding surface and the upper surface such that the upper surface has an upper surface area which is larger than a surface area of the bonding surface.

122. The light emitting device of claim **111**, where the lateral sides are inclined between the bonding surface and the upper surface such that the upper surface has an upper surface area which is smaller than a surface area of the bonding surface.

123. The light emitting device of claim **111**, wherein the mounting substrate comprises a thermal transfer element.

124. The light emitting device of claim **111**, wherein the package defines a cavity in which the one or more LEDs are disposed.

125. The light emitting device of claim **111**, wherein the one or more LEDS comprise substantially vertical lateral sides.

126. The light emitting device according to claim **111**, comprising a minimum of approximately 65 CRI for Cool White (CW) color points or a minimum of approximately 80 CRI for Warm White (WW) color points.

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